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(54) **RESONATOR FOR RADIO FREQUENCY SIGNALS**

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H01P 1/208 (2006.01)
H01P 1/06 (2006.01)
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(58) **Field of Classification Search**

CPC H01P 7/06; H01P 1/207; H01P 1/208
See application file for complete search history.

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(57) **ABSTRACT**

A resonator for radio frequency, RF, signals, said resonator comprising a cavity having a longitudinal axis, a first wall, at least one side wall, and a lid arranged opposite the first wall, wherein said resonator further comprises a guiding device which is arranged at said at least one side wall and is configured to guide an axial movement of said lid along said longitudinal axis.

10 Claims, 8 Drawing Sheets

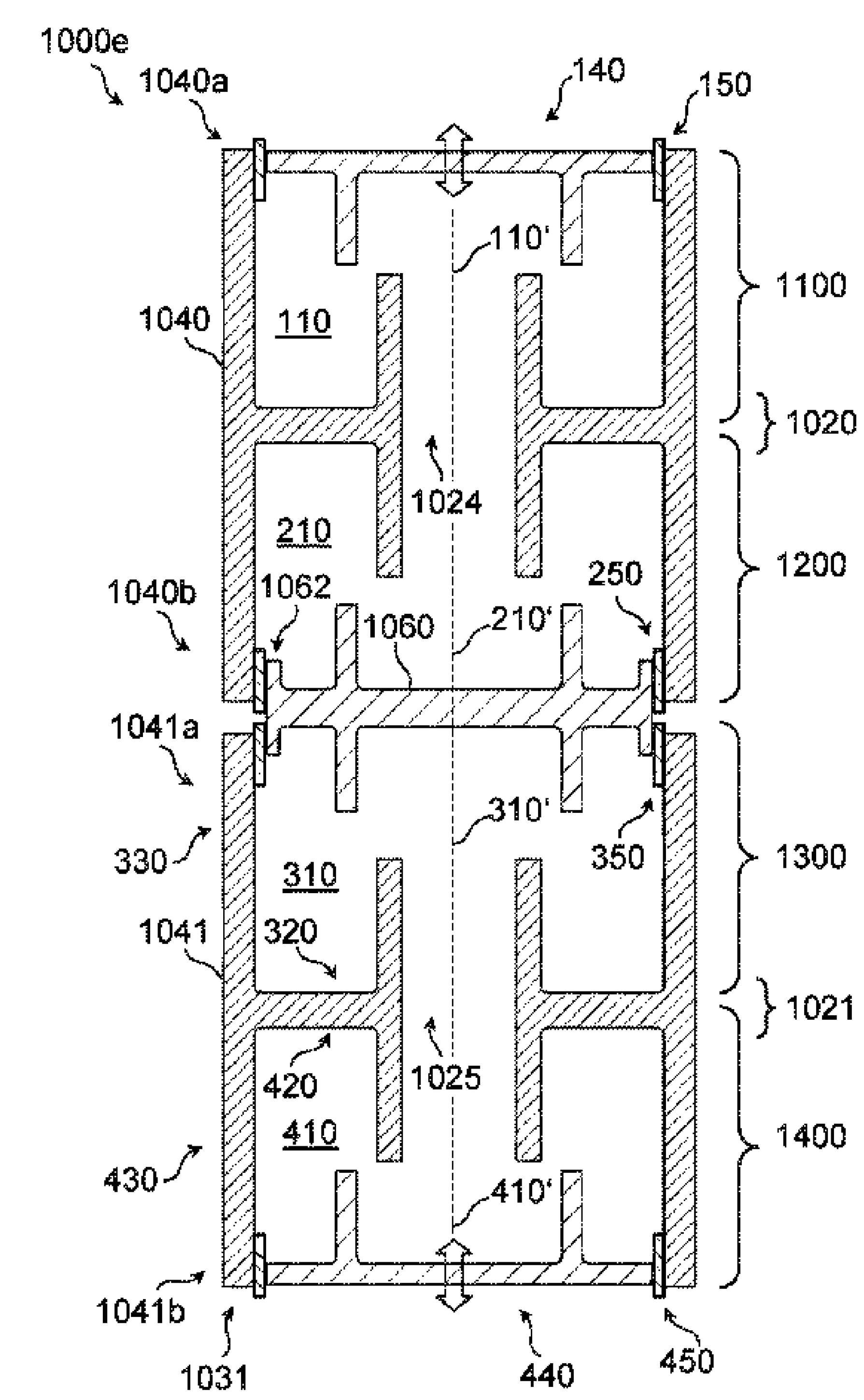

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Fig. 1

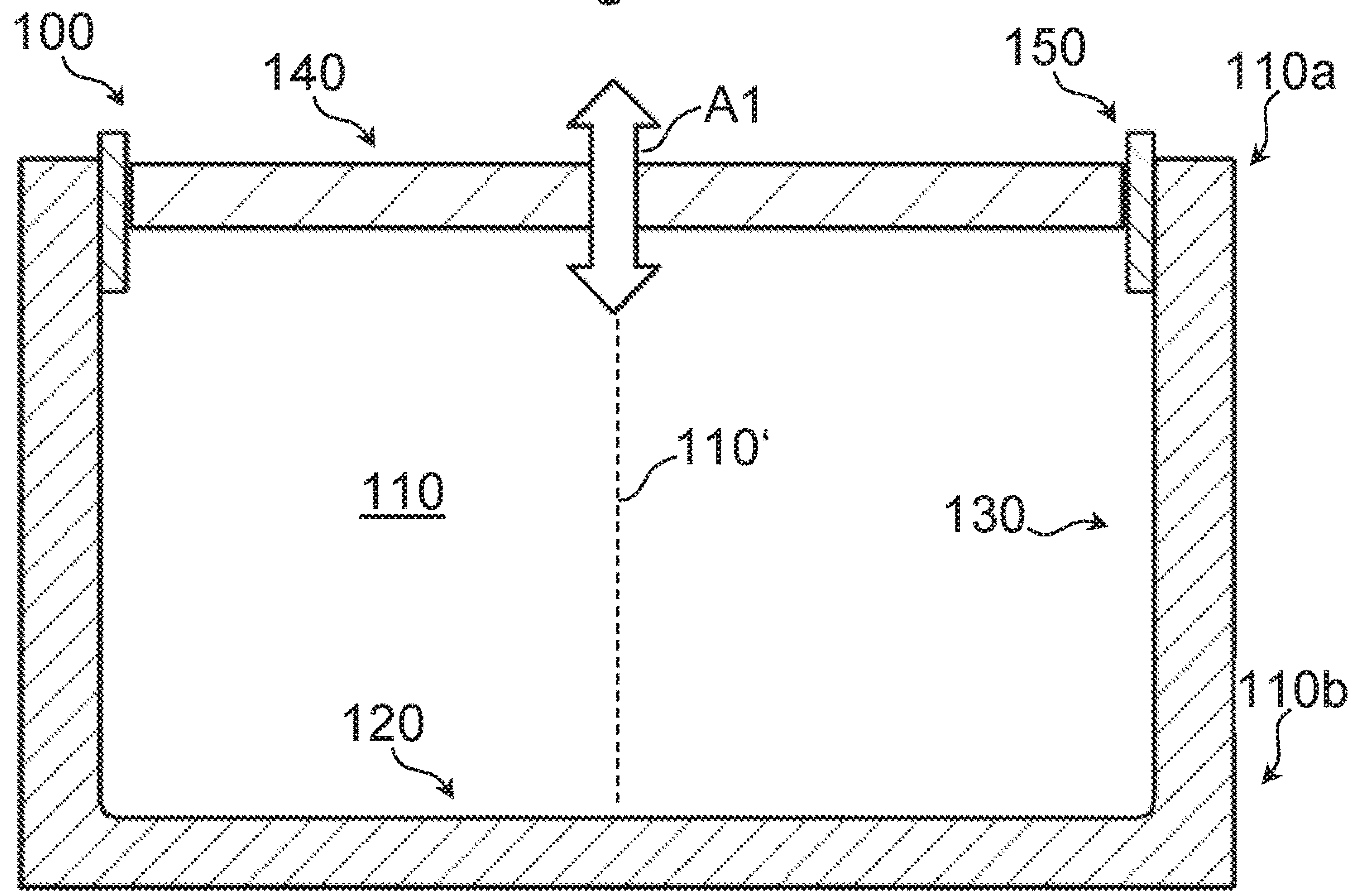

Fig. 2A

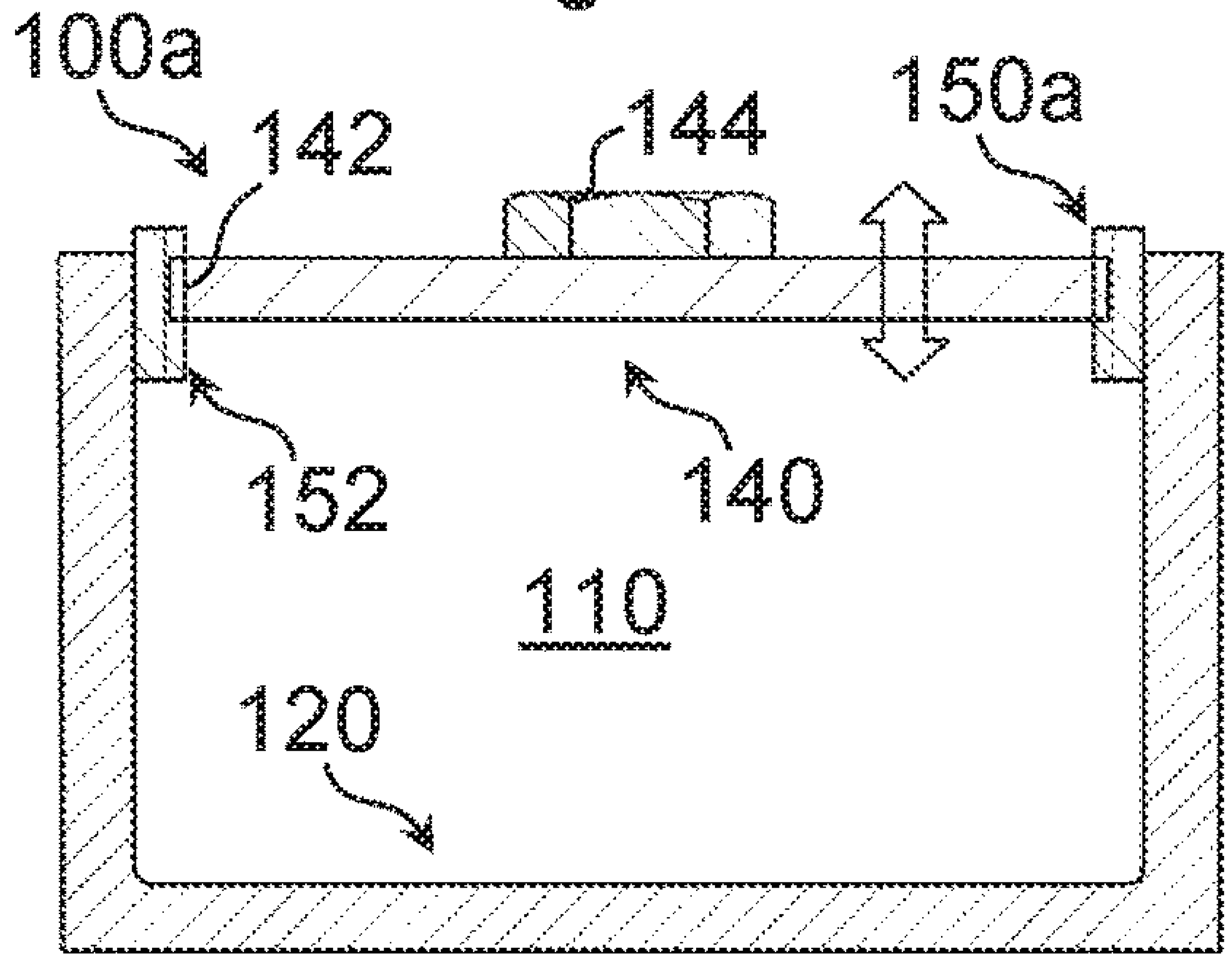

Fig. 2B

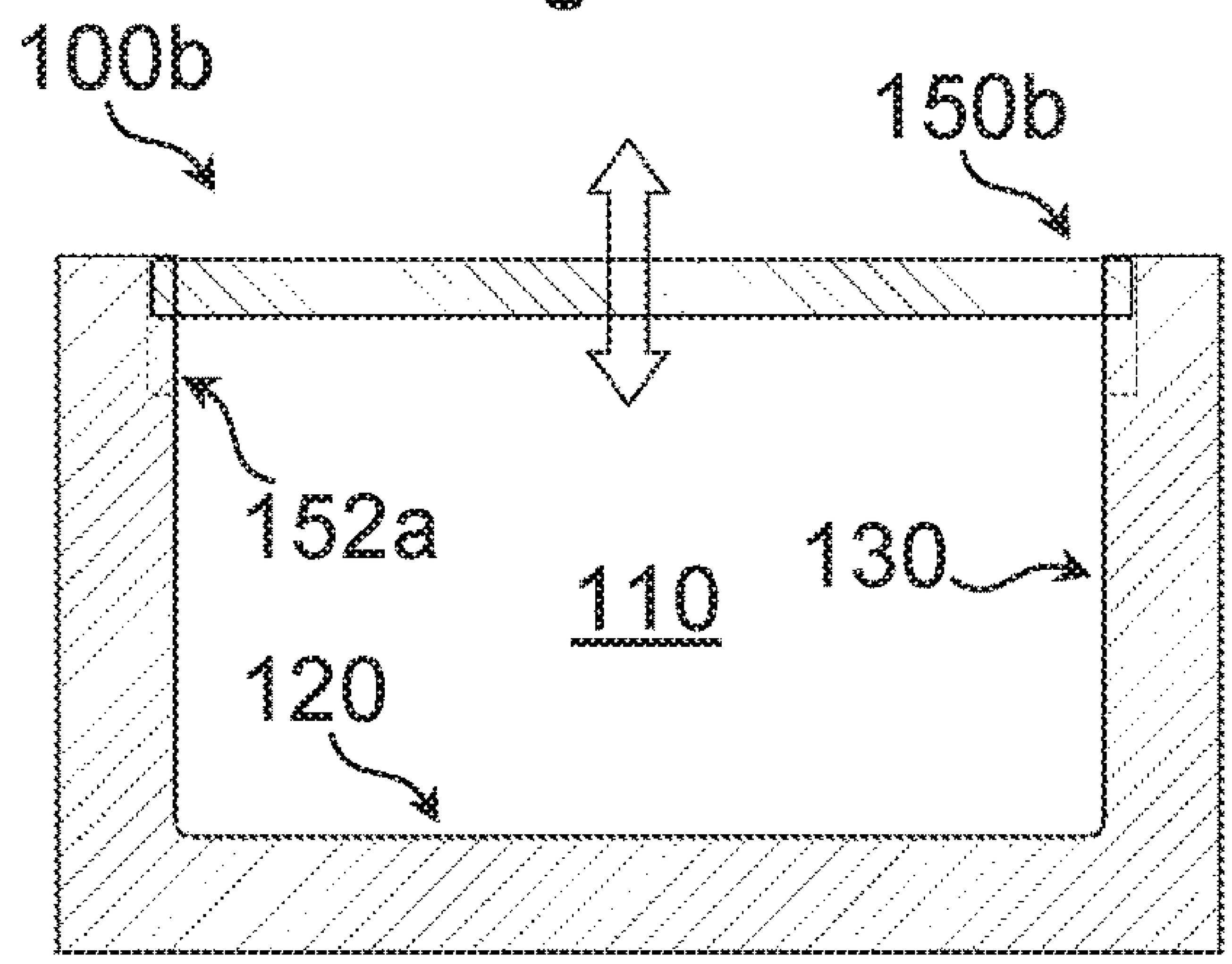

Fig. 2C

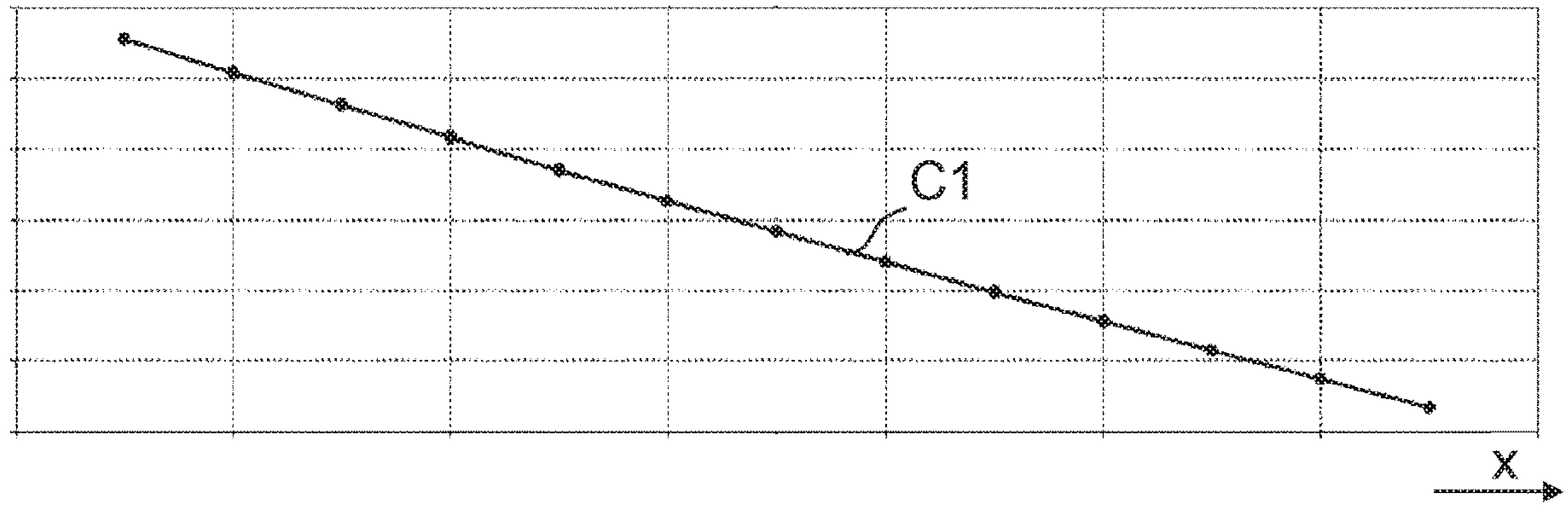

Fig. 3

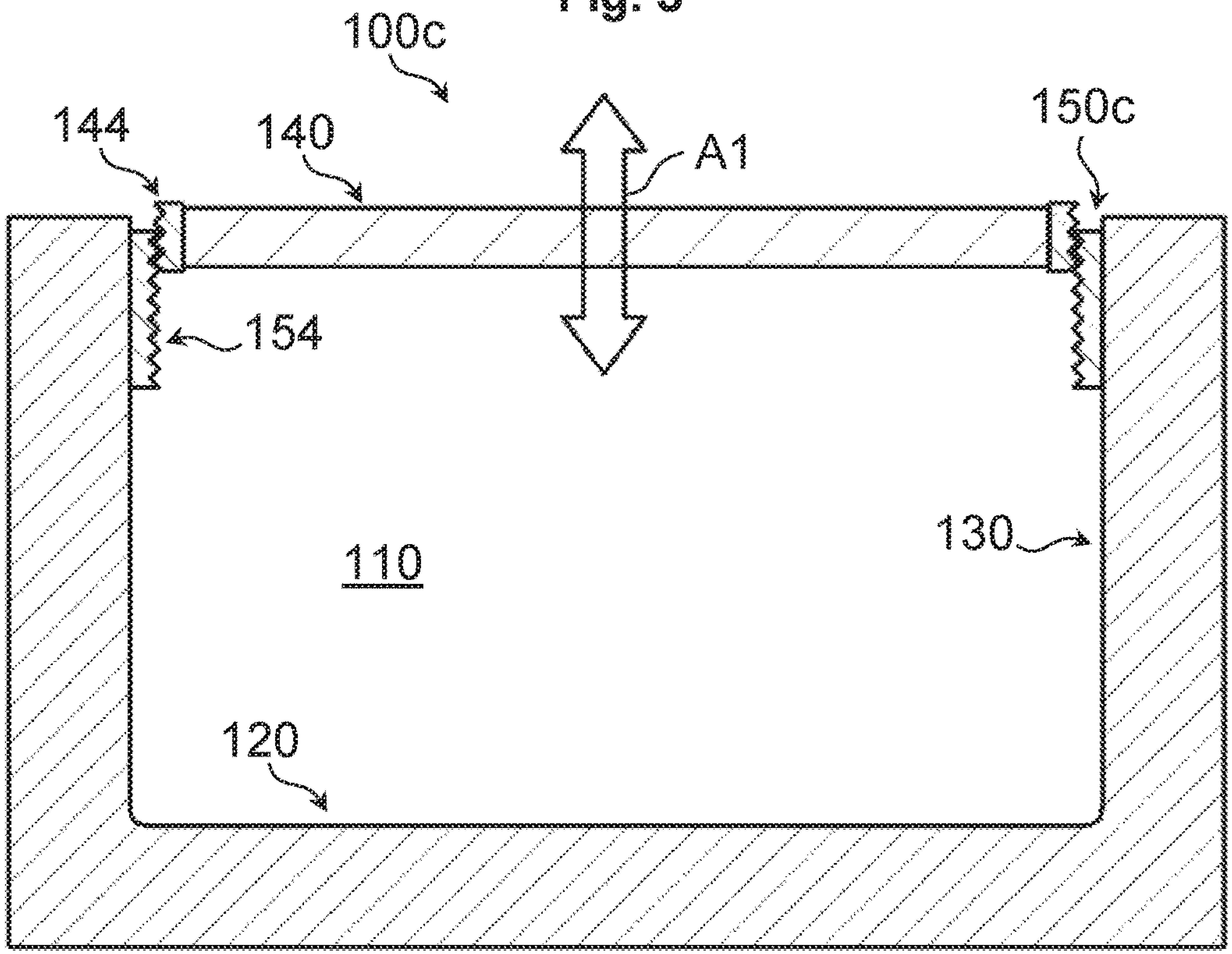
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Fig. 4

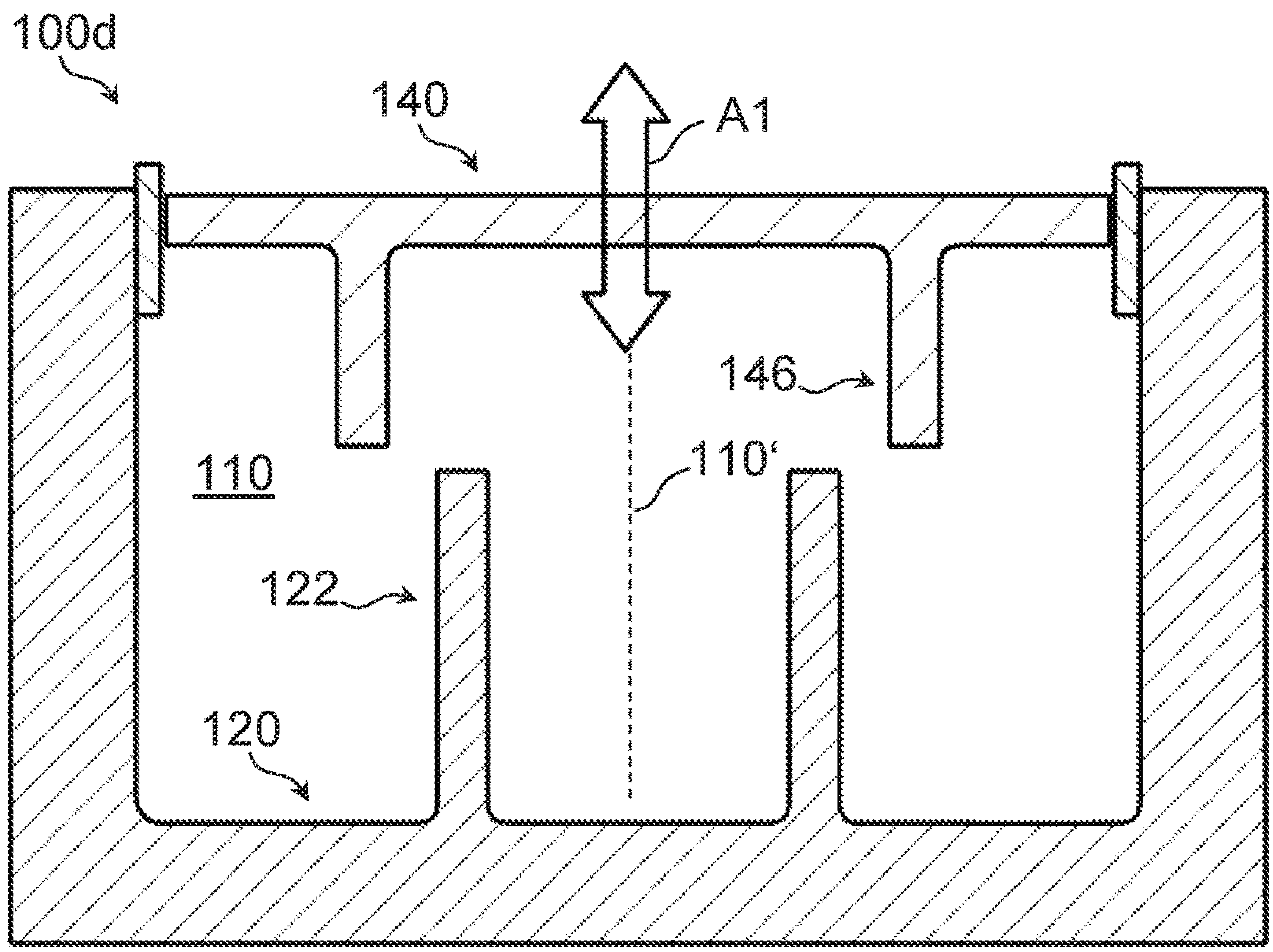
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Fig. 5A

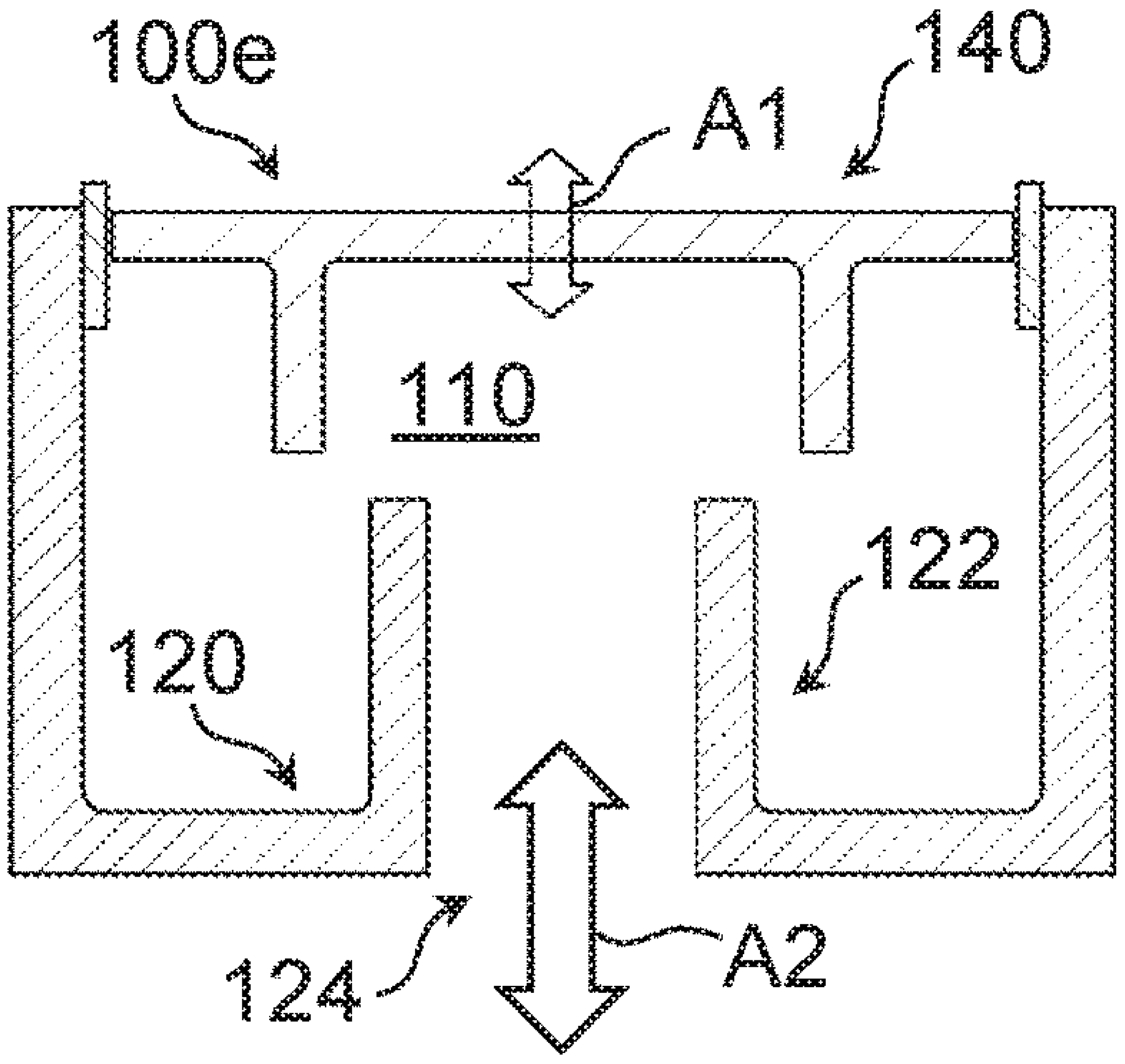

Fig. 5B

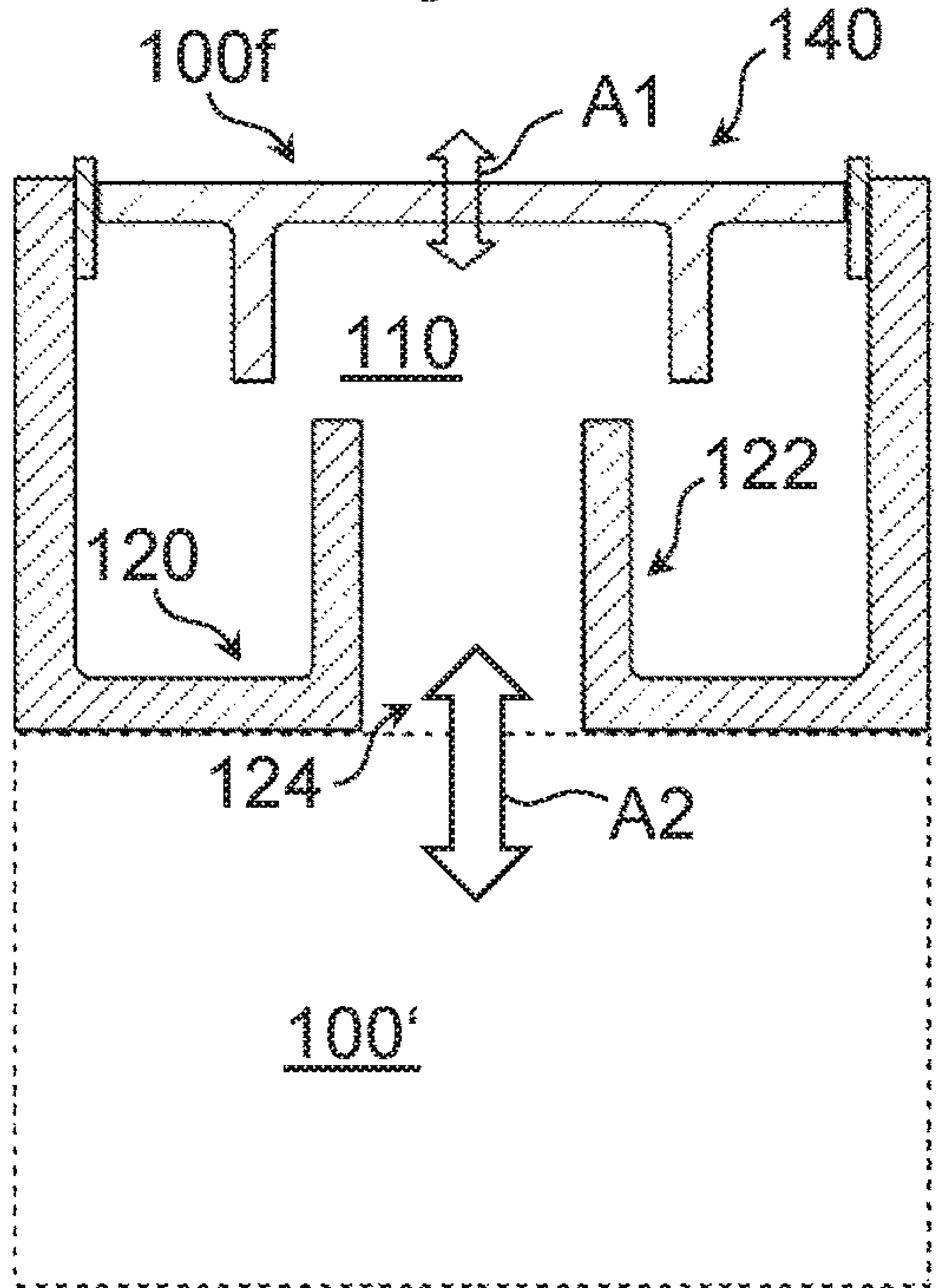

Fig. 6A

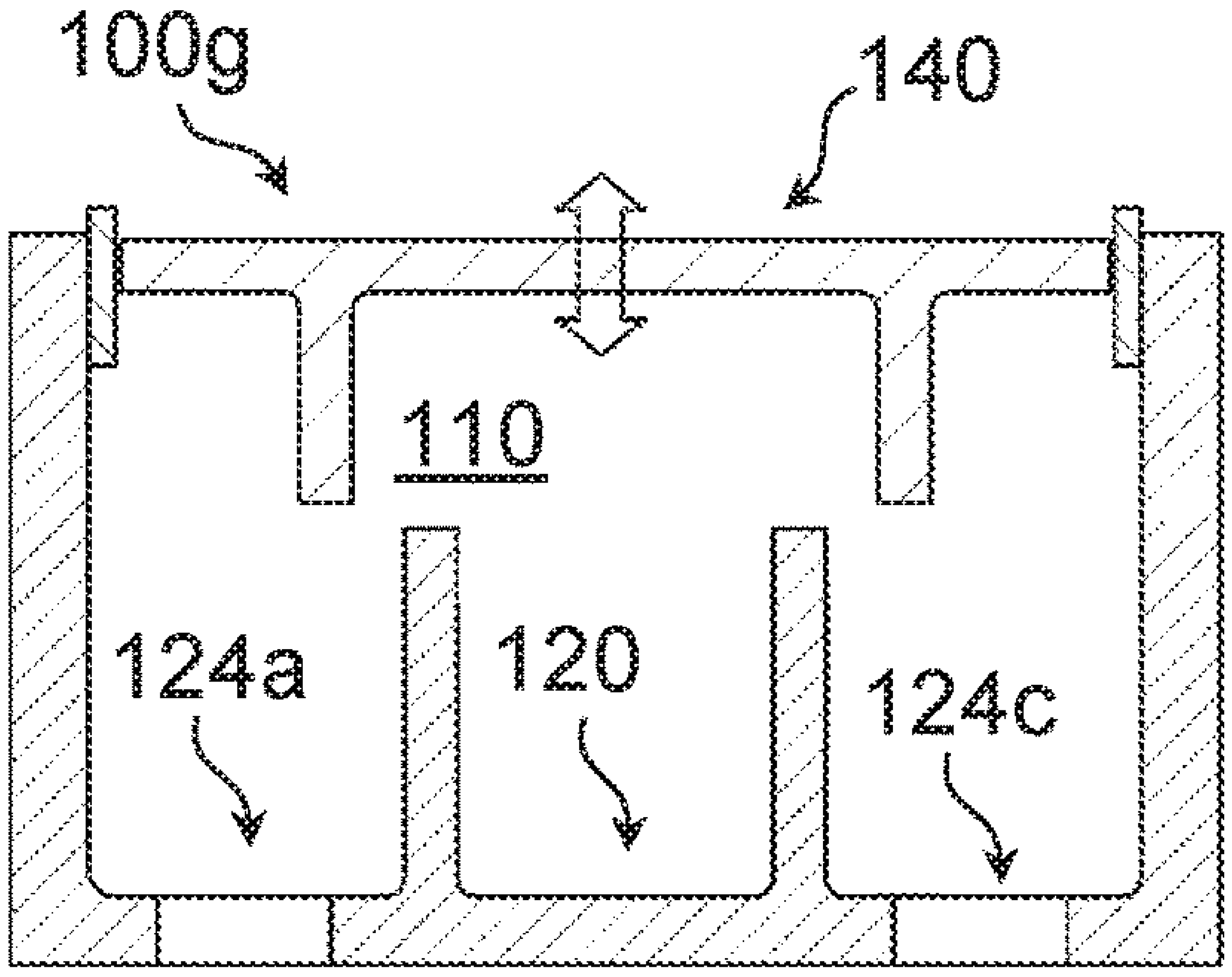

Fig. 6B

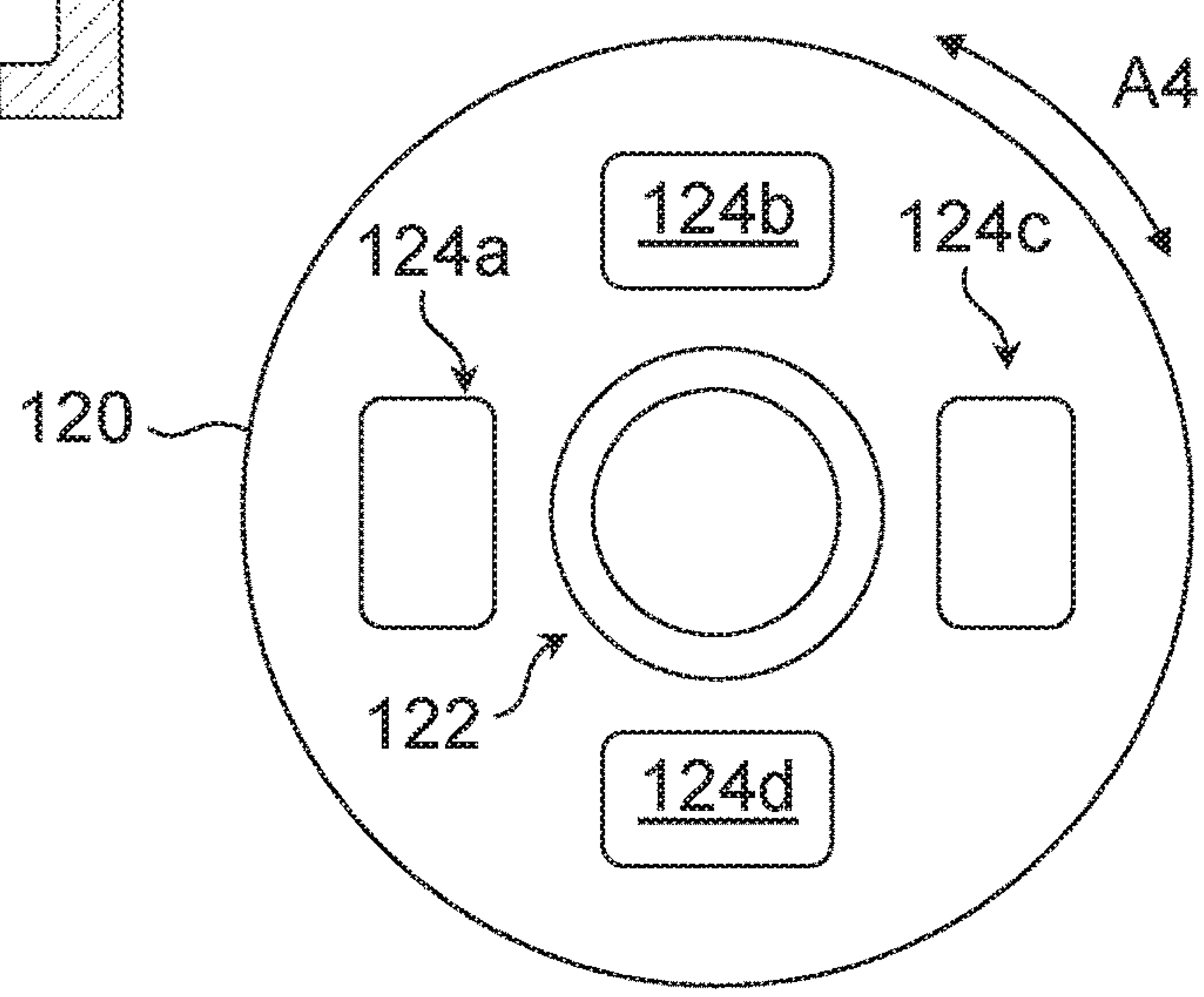

Fig. 7

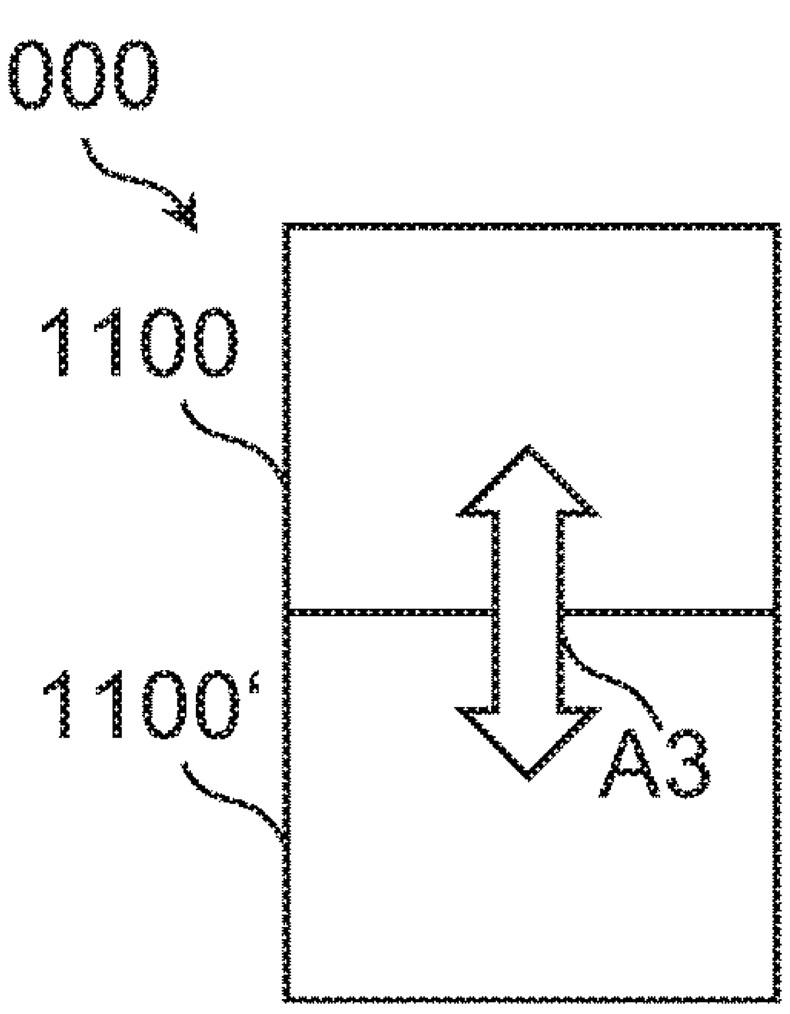

Fig. 8

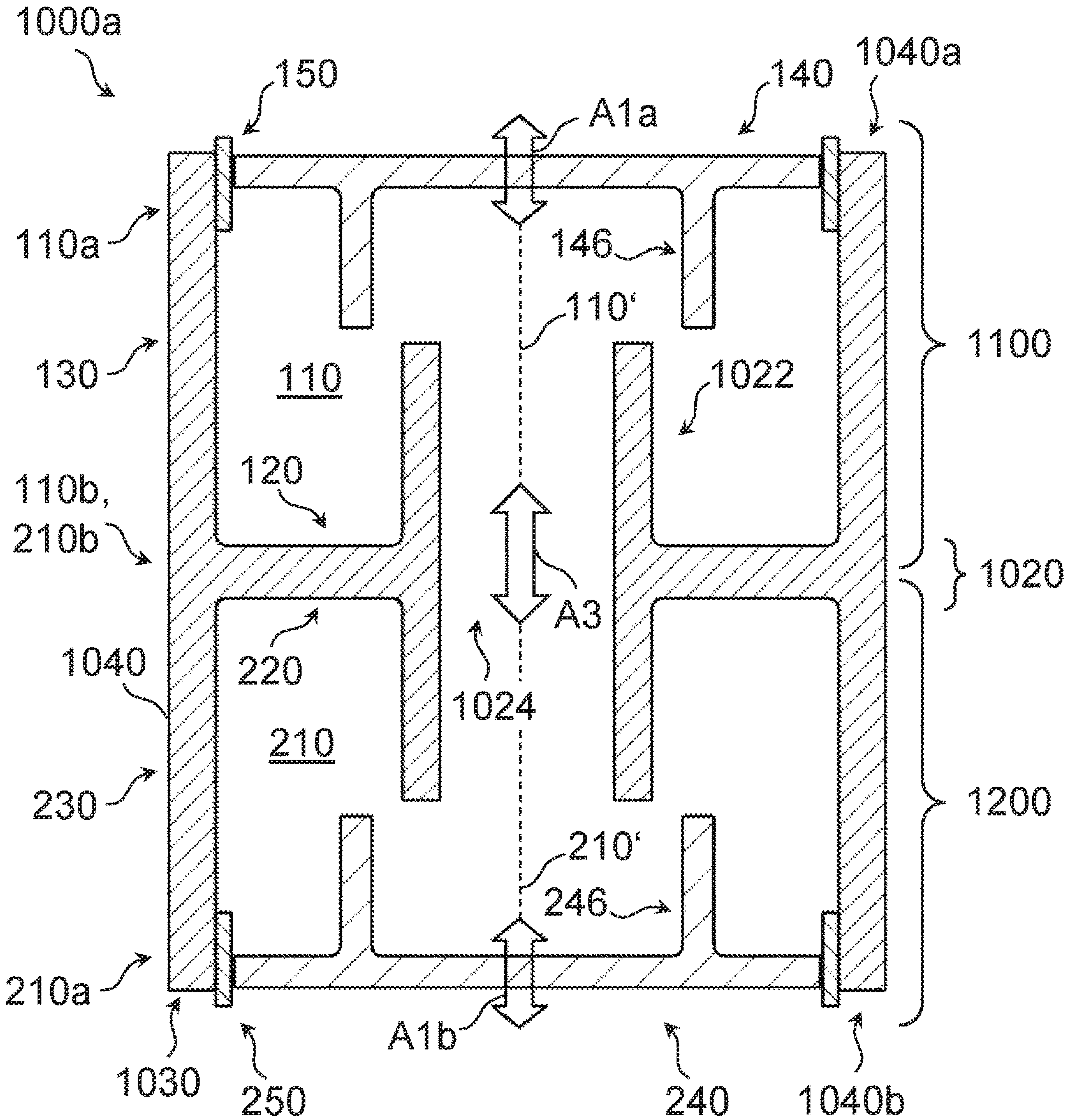

Fig. 9A

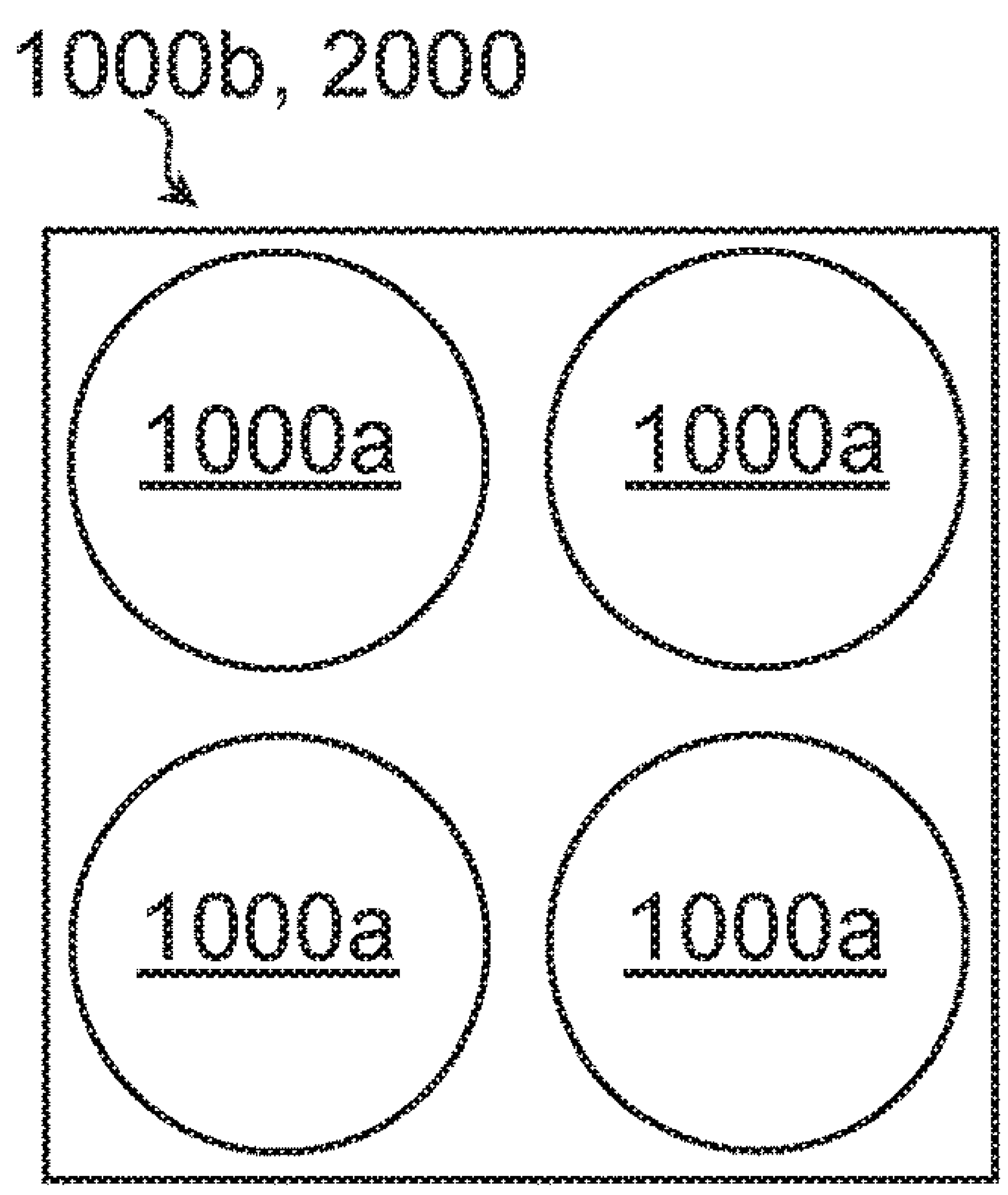

Fig. 9B

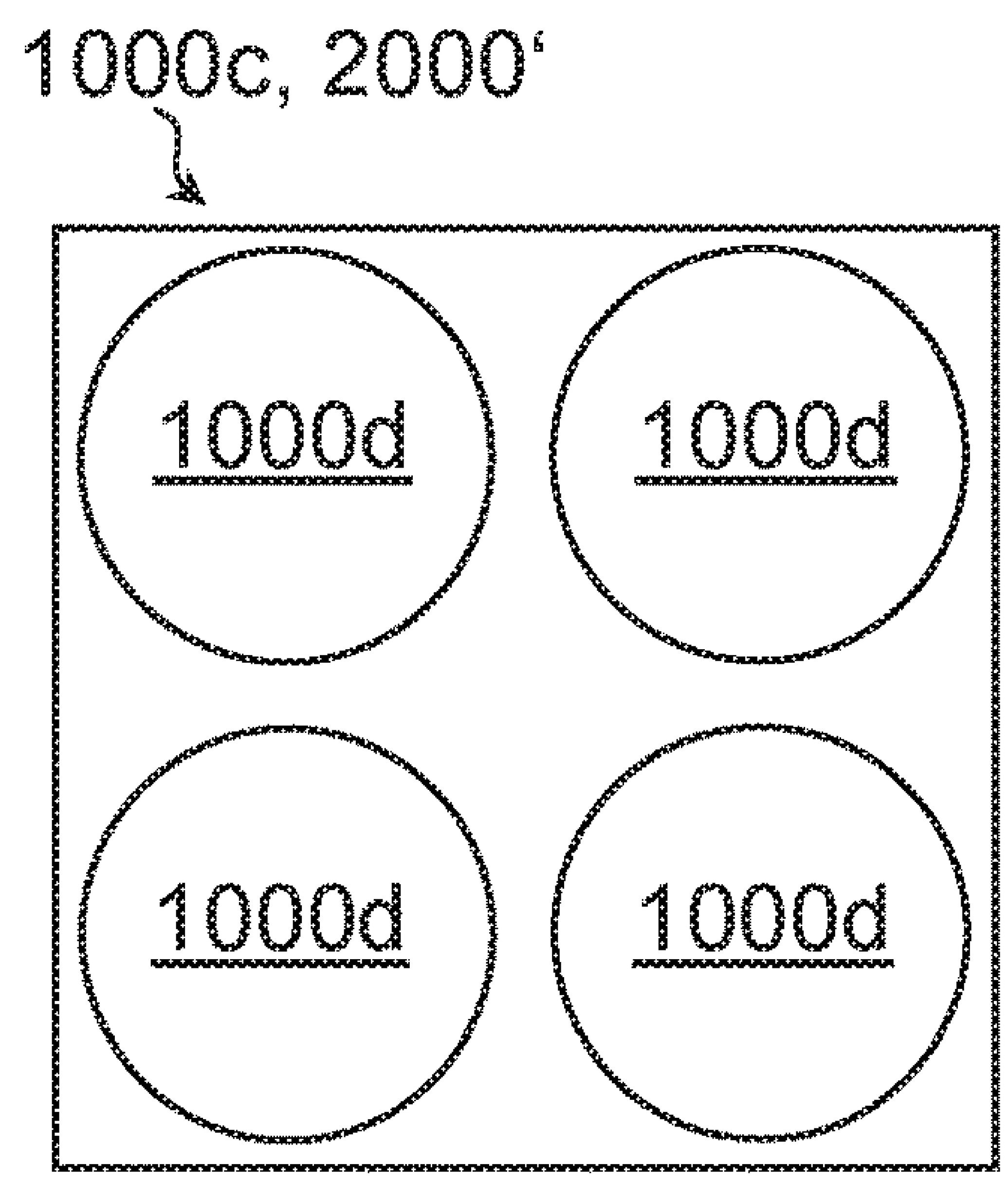

Fig. 10

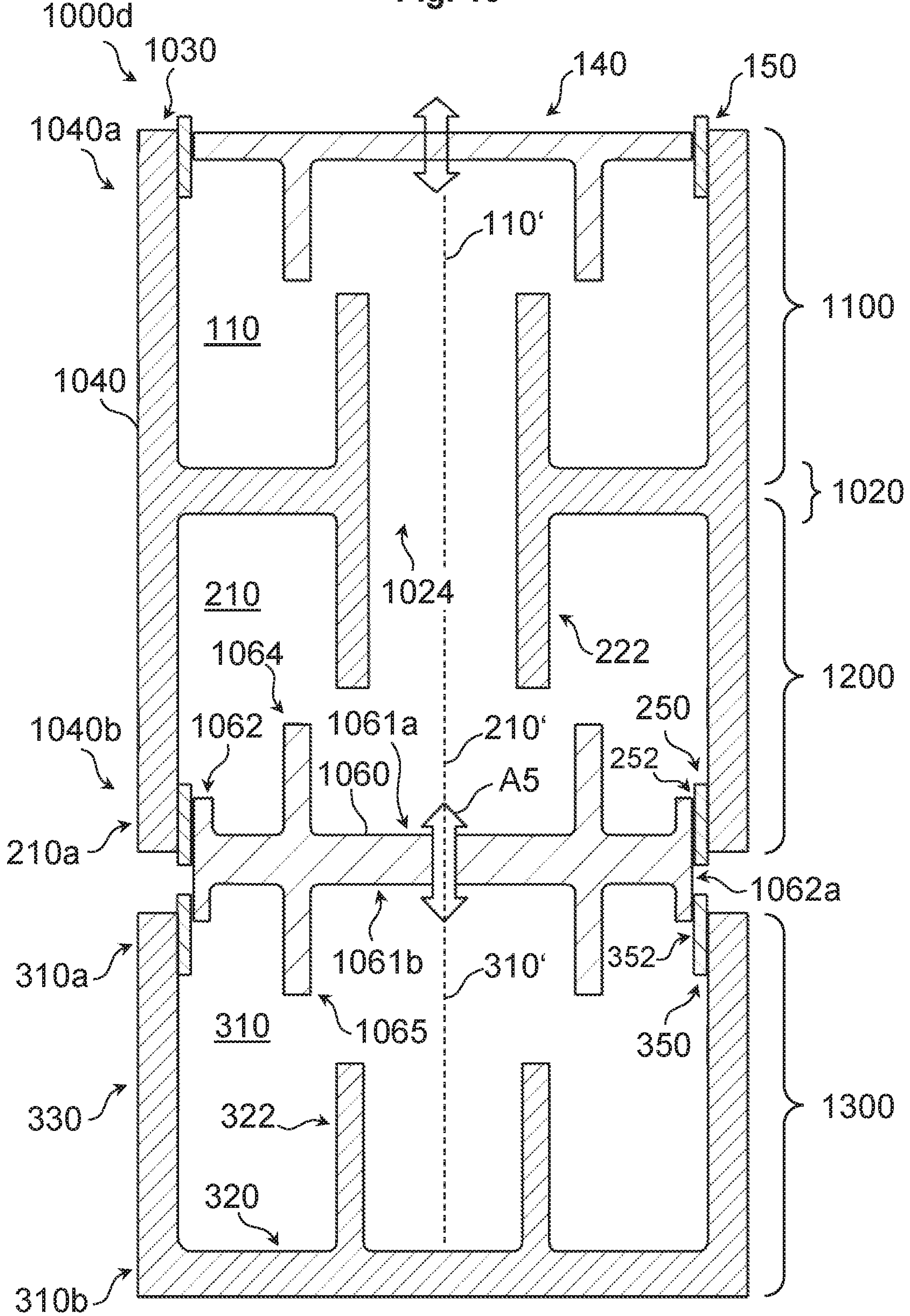
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Fig. 11

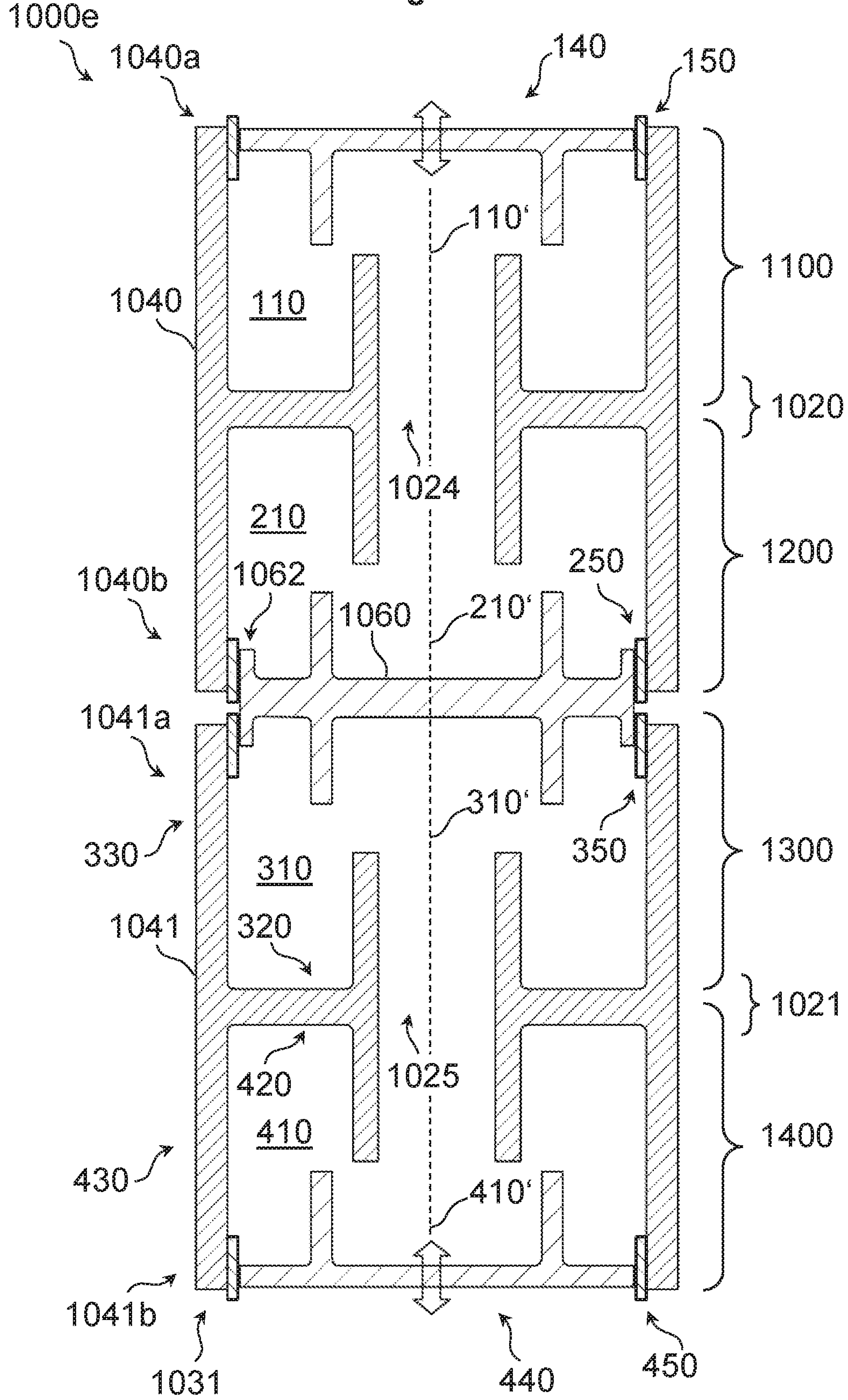
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Fig. 12A

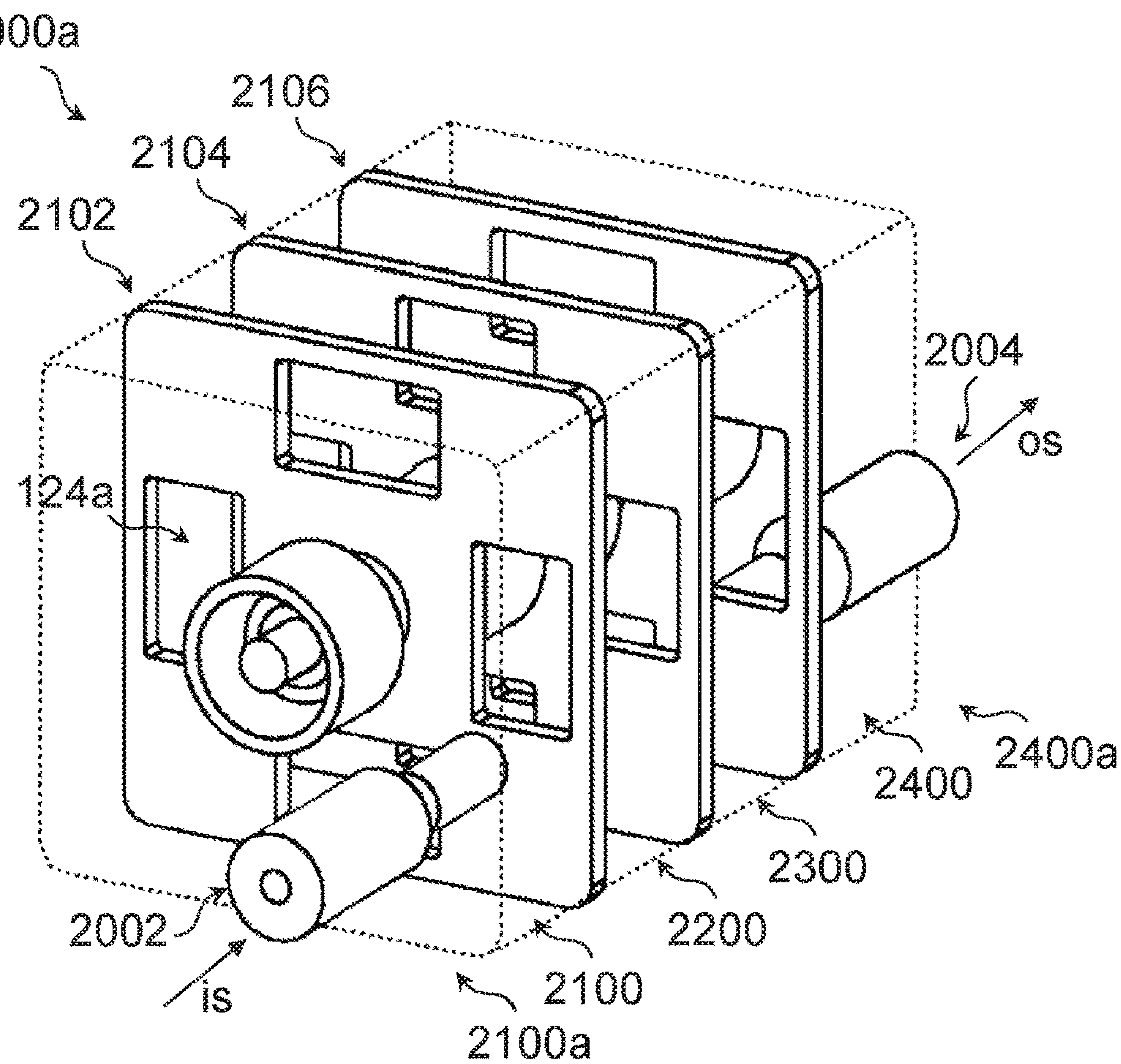


Fig. 12B

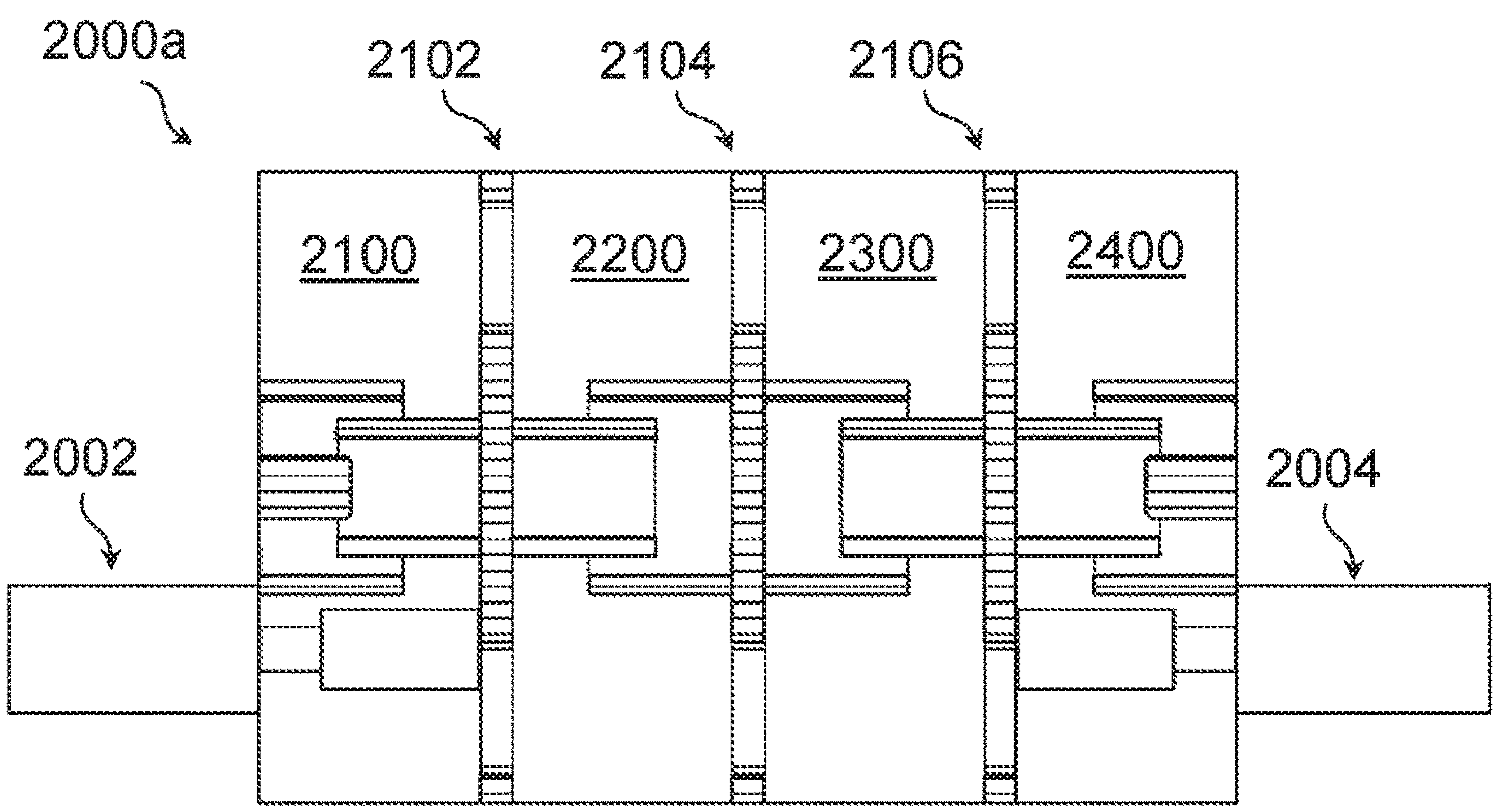


Fig. 12C

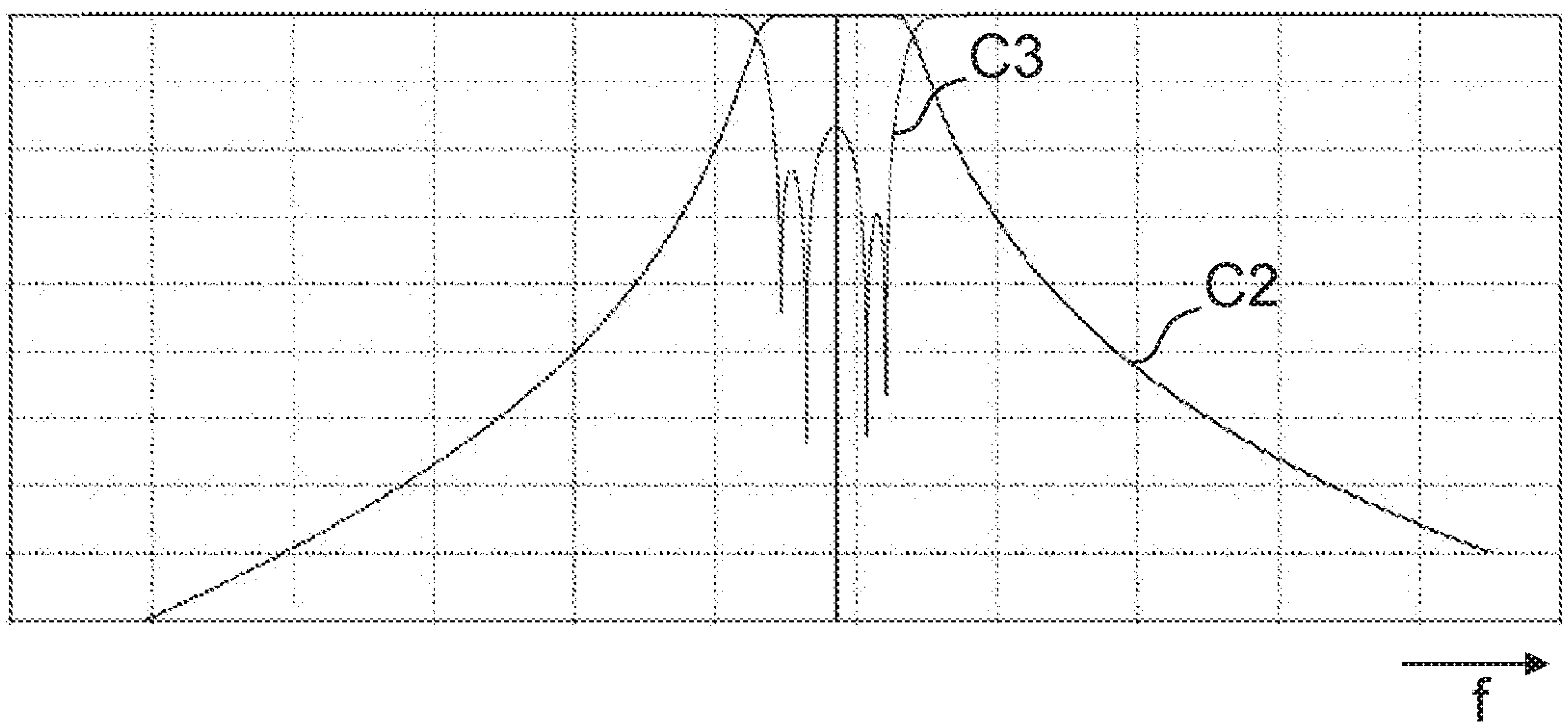
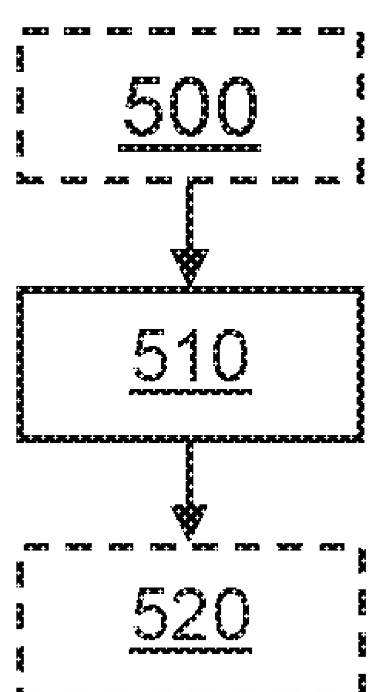


Fig. 13



RESONATOR FOR RADIO FREQUENCY SIGNALS

RELATED APPLICATION

This application claims priority benefit from European Patent Application No. 18209445.8 filed Nov. 30, 2018 the content of which is hereby incorporated by reference in its entirety.

FIELD OF THE INVENTION

Exemplary embodiments relate to a resonator for radio frequency, RF, signals.

Further exemplary embodiments relate to a filter for RF signals.

Further exemplary embodiments relate to a method of filtering RF signals.

BACKGROUND

Resonators for RF signals may be used to provide filters for RF signals.

SUMMARY

Exemplary embodiments relate to a resonator for radio frequency, RF, signals, said resonator comprising a cavity having a longitudinal axis, a first wall, at least one side wall, and a lid arranged opposite the first wall, wherein said resonator further comprises a guiding device which is arranged at said at least one side wall and is configured to guide an axial movement of said lid along said longitudinal axis. This enables an efficient tuning of the resonator, particularly of a resonant frequency of said resonator. Thus, no further, separate tuning elements as known from conventional systems are required for tuning said resonator.

According to further exemplary embodiments, said first wall may be a bottom wall of the resonator, and/or said lid may be a top wall of the resonator.

According to further exemplary embodiments, said cavity may comprise a rectangular cross-section. According to further exemplary embodiments, said cavity may comprise a circular cross-section.

According to further exemplary embodiments, said guiding device comprises a first thread, preferably an internal (i.e., female) thread, and said lid comprises a second thread, preferably an external (i.e., male) thread that fits to said first thread of said guiding device. Thus, a precise tuning of the resonator's resonant frequency is enabled by rotating said lid within the guiding device. In these embodiments, the guiding device is configured to guide both a rotational movement and said axial movement of the lid with respect to the resonator's cavity.

According to further exemplary embodiments, said guiding device comprises a first serrated surface, and said lid comprises a second serrated surface that fits to said first serrated surface of said guiding device. This enables a stepwise axial movement of said lid relative to said cavity, i.e. without rotation of said lid. According to further exemplary embodiments, the serrated surfaces may be provided in the form of a "step slide", or generally by any structure enabling—at least to some extent—form closure between the lid and the side wall(s) to retain the lid in its place in the absence of external forces. However, if an external force is applied, e.g. in an axial direction, said force exceeding a predetermined threshold (e.g. the retention force of the form closure), the lid may be moved axially to effect tuning.

According to further exemplary embodiments, a step size of said stepwise axial movement (and/or a force required to effect said movement, i.e. to at least temporarily overcome said form closure) may be controlled by providing the serrated surfaces with a corresponding geometry. According to further exemplary embodiments, guiding means comprising said serrated surfaces may be used with rectangular and/or circular cross-section of said cavity, while according to other exemplary embodiments guiding means comprising threads are preferably used with a circular cross-section of said cavity.

According to further exemplary embodiments, said guiding device is arranged in a first axial end section of said cavity (having rectangular or circular cross-section, e.g.), and said first wall (for example, bottom wall) is arranged in a second axial end section of said side wall.

According to further exemplary embodiments, said first wall comprises at least one resonator post extending into said cavity (preferably perpendicular to an inner surface of said first wall). According to further exemplary embodiments, said at least one resonator post comprises a circular cylindrical shape. According to further exemplary embodiments, said at least one resonator post comprises a hollow (circular) cylindrical shape. According to further exemplary embodiments, said at least one resonator post is arranged coaxially with respect to the longitudinal axis of the cavity.

According to further exemplary embodiments, said lid comprises at least one resonator post extending into said cavity, preferably perpendicular to an inner surface of said lid. According to further exemplary embodiments, said at least one resonator post of said lid comprises a circular cylindrical shape. According to further exemplary embodiments, said at least one resonator post comprises a hollow (circular) cylindrical shape.

According to further exemplary embodiments, said at least one resonator post is arranged coaxially with respect to the longitudinal axis of the cavity and/or an optional resonator post extending from said first wall into said cavity.

According to further exemplary embodiments, said first wall comprises at least one opening, which enables to exchange RF signals and/or generally electromagnetic energy with an adjacent volume such as an optional neighboring further resonator and/or any other component or system configured to be coupled to said resonator. According to further exemplary embodiments, said at least one opening of said first wall comprises a circular (and/or circular ring) shape, preferably arranged coaxially with the longitudinal axis of the cavity of said resonator. According to further exemplary embodiments, a plurality of openings may be provided in said first wall, wherein preferably said plurality of openings is arranged circumferentially around said longitudinal axis of the cavity. According to further exemplary embodiments, at least one of said plurality of openings may comprise a rectangular shape, preferably with rounded edges.

According to further embodiments, said at least one lid comprises a profile, e.g. screw profile, for example a hexagonal profile, e.g. similar to a hex nut, which facilitates driving a rotational movement of said lid, e.g. for tuning the resonator cavity associated with said lid. According to further embodiments, said profile is provided on a surface of said lid, preferably an outer surface of said lid, to enable easy access from the outside of the resonator.

Further exemplary embodiments relate to an apparatus comprising a first resonator according to at least one of the preceding claims and at least one further resonator for radio frequency, RF, signals which is preferably coupled with said first resonator. This way, a compact and mechanically stable configuration having two resonators may be provided, wherein at least the first resonator is efficiently tunable regarding its resonant frequency by means of at least axially moving its lid.

According to further exemplary embodiments, said at least one further resonator of said apparatus may be a resonator according to the embodiments. This way, a compact and mechanically stable configuration having two resonators may be provided, wherein at least the first resonator and the further resonator are efficiently tunable regarding their resonant frequency by means of at least axially moving the respective lid.

According to further exemplary embodiments, said at least one further resonator may be a conventional resonator. According to further exemplary embodiments, said first resonator and said at least one further resonator (or their respective cavities) are not coupled with each other.

According to further exemplary embodiments, said at least one further resonator is a second resonator, wherein said second resonator comprises a configuration according to the embodiments. I.e., according to further exemplary embodiments, said second resonator comprises a cavity having a longitudinal axis, a first wall, at least one side wall, and a lid arranged opposite the first wall, wherein said second resonator further comprises a guiding device which is arranged at said at least one side wall and is configured to guide an axial movement of said lid along said longitudinal axis (preferably at least an axial movement, in case of e.g. serrated surfaces, and both a rotational and an axial movement in case of a thread connection between the guiding device and the lid).

According to further exemplary embodiments, the first wall of the first resonator and the first wall of the second resonator are adjacent to each other forming a common wall which at least partly (e.g., apart from one or more optional openings for RF signal coupling) separates the cavity of the first resonator and the cavity of the second resonator from each other, wherein preferably said common wall comprises at least one opening. This enables a particularly small configuration of the apparatus, which may also be referred to as "stacked configuration", because the first resonator and the second resonator may be arranged together along the longitudinal axis of their cavities. According to further exemplary embodiments, the first resonator and the second resonator are arranged relative to each other such that the longitudinal axes of their respective cavities are collinear.

According to further exemplary embodiments, said at least one opening of said common wall comprises a circular (and/or circular ring) shape, preferably arranged coaxial with the longitudinal axis of at least one adjacent cavity. According to further exemplary embodiments, a plurality of openings may be provided in said common wall, wherein preferably said plurality of openings is arranged circumferentially around the longitudinal axis of said at least one adjacent cavity. According to further exemplary embodiments, at least one of said plurality of openings may comprise a rectangular shape, preferably with rounded edges.

According to further exemplary embodiments, the cavity of the first resonator may have a first geometry, e.g. particular cross-section (shape and/or size), and the cavity of the second resonator may have a second geometry, e.g. particular cross-section, wherein said second geometry is different from said first geometry. According to further exemplary embodiments, the second geometry may be similar or identical to the first geometry.

According to further exemplary embodiments, said at least one side wall of the first resonator and said at least one side wall of the second resonator are made of one piece forming a common side wall for both said first cavity and said second cavity, which yields a particularly compact configuration with high mechanical stability.

According to further exemplary embodiments, said common wall and said common side wall are made of one piece.

According to further exemplary embodiments, a third resonator with a cavity is provided, wherein said third resonator comprises at least one side wall and is arranged such that a first axial end section of its cavity faces a first axial end section of the cavity of the second resonator, wherein a common lid is provided between the second resonator and the third resonator, said common lid at least partly, preferably fully, covering the cavity of the second resonator and the cavity of the third resonator. This way, a compact and mechanically stable configuration having three resonators may be provided, wherein at least the first resonator is efficiently tunable regarding its resonant frequency by means of at least axially moving its lid.

According to further exemplary embodiments, said apparatus further comprises a fourth resonator with a cavity, a first wall, and at least one side wall, wherein a first wall of the third resonator and the first wall of the fourth resonator are adjacent to each other forming a further common wall which at least partly (e.g., apart from one or more optional openings for RF signal coupling) separates the cavity of the third resonator and the cavity of the fourth resonator from each other. This way, a compact and mechanically stable configuration having four resonators may be provided, wherein at least the first resonator and/or the further resonator are efficiently tunable regarding their resonant frequency by means of at least axially moving their respective lid.

According to further exemplary embodiments, the shape of said fourth resonator is similar or identical to the shape of the first and/or second resonator. As an example, the fourth resonator may also comprise an (at least) axially movable lid opposing said further common wall, which enables individual tuning of the resonant frequency of said fourth resonator.

According to further exemplary embodiments, said further common wall comprises at least one opening, which enables RF signal coupling between the cavity of the third resonator and the cavity of the fourth resonator. According to further exemplary embodiments, said at least one opening of said further common wall comprises a circular (and/or circular ring) shape, preferably arranged coaxial with the longitudinal axis of at least one adjacent cavity.

According to further exemplary embodiments, a plurality of openings may be provided in said further common wall, wherein preferably said plurality of openings is arranged circumferentially around the longitudinal axis of said at least one adjacent cavity.

According to further exemplary embodiments, at least one of said plurality of openings may comprise a rectangular shape, preferably with rounded edges.

According to further exemplary embodiments, said at least one side wall of the third resonator and said at least one side wall of the fourth resonator are made of one piece forming a further common side wall for both the cavity of the third resonator and the cavity of the fourth resonator.

According to further exemplary embodiments, said further common wall and said further common side wall are made of one piece, which enables a mechanically stable and yet compact design.

According to further exemplary embodiments, said second resonator comprises a guiding device which is arranged at a first axial end section of said cavity of the second resonator and is configured to guide an axial movement of said common lid with respect to said cavity of the second resonator along a longitudinal axis of said cavity of the second resonator. This enables to tune the resonant frequency of the cavity of the second resonator by means of at least axially moving its lid.

According to further exemplary embodiments, said guiding device of said second resonator may have a configuration similar or identical to the guiding device of the first resonator. This way, by axially moving the lid of the first resonator, the resonant frequency of the cavity of the first resonator may be tuned, and by axially moving the common lid relative to the cavity of the second resonator, the resonant frequency of the cavity of the second resonator may be tuned.

According to further exemplary embodiments, said third resonator comprises a guiding device which is arranged at a first axial end section of said cavity of the third resonator and is configured to guide an axial movement of said common lid with respect to said cavity of the third resonator along a longitudinal axis of said cavity of the third resonator. This enables to tune the resonant frequency of the cavity of the third resonator by means of at least axially moving the common lid relative to the cavity of the third resonator.

According to further exemplary embodiments, said piece comprising said further common wall and said further common side wall may be moved, together with said common lid (i.e., there is no relative movement between said piece and said common lid), axially with respect to the second resonator, whereby the resonant frequency of the cavity of the second resonator may be tuned, whereas the resonant frequency of the cavity of the third resonator is not altered as the common lid is not moved axially with respect to said cavity of the third resonator while tuning said second resonator.

According to further exemplary embodiments, said piece comprising said further common wall and said further common side wall may be moved axially with respect to the common lid, whereby the resonant frequency of the cavity of the third resonator may be tuned, whereas the resonant frequency of the cavity of the second resonator, which is adjacent to said common lid, is not altered as the common lid is not required to be moved axially with respect to said cavity of the second resonator while tuning said third resonator.

According to further exemplary embodiments, said guiding device of the second resonator comprises a thread, preferably an inner (i.e., female) thread, wherein said common lid also comprises a thread, preferably an outer (i.e., male) thread that fits to said thread of said guiding device of the second resonator.

According to further exemplary embodiments, said guiding device of the third resonator comprises a thread, preferably an inner (i.e., female) thread, wherein said common lid also comprises a thread, preferably an outer (i.e., male) thread that fits to said thread of said guiding device of the third resonator.

According to further exemplary embodiments, at least one lid of said resonator comprises a circular cylindric shape, e.g. circular disc shape.

According to further exemplary embodiments, said common lid comprises a circular cylindric shape, e.g. circular disc shape. According to further exemplary embodiments, said common lid may comprise a radially outer section of said circular cylindric shape, where an outer (i.e., male) thread is provided which fits to the inner thread of said guiding device of the second resonator and/or the guiding device of the third resonator. According to further exemplary embodiments, said common lid is designed such that its outer thread can be screwed into both the inner thread of the guiding device of the second resonator and the inner thread of the guiding device of the third resonator at the same time.

According to further exemplary embodiments, an axial length (i.e., as seen parallel to a longitudinal axis of the apparatus and/or at least one of its resonator cavities) of said outer thread of the common lid is chosen such that a) it can be screwed into both the inner thread of the guiding device of the second resonator and the inner thread of the guiding device of the third resonator at the same time, thus mechanically coupling the second resonator and the third resonator with each other, and b) tuning of the second and/or third resonator is still possible, i.e. by screwing the common lid further into/out of the second and/or third resonator or the respective guiding devices of said resonators.

According to further exemplary embodiments, said common lid comprises at least one resonator post extending into at least one cavity adjacent to said common lid. According to further exemplary embodiments, said at least one resonator post of said common lid may be arranged on a first surface of said common lid facing the cavity of the second resonator, such that said at least one resonator post of the common lid extends into said cavity of the second resonator. According to further exemplary embodiments, said at least one resonator post of said common lid may be arranged on a second surface of said common lid facing the cavity of the third resonator, such that said at least one resonator post of the common lid extends into said cavity of the third resonator. According to further exemplary embodiments, at least one resonator post of said common lid may be arranged on said first surface of said common lid, and at least one (further) resonator post of said common lid may be arranged on said second surface.

According to further exemplary embodiments, said at least one resonator post of said common lid comprises a circular cylindrical shape. According to further exemplary embodiments, said at least one resonator post of said common lid comprises a hollow (circular) cylindrical shape. According to further exemplary embodiments, said at least one resonator post of said common lid is arranged coaxially with respect to a longitudinal axis of an adjacent cavity (i.e., of the second and/or third resonator) and/or with respect to an optional resonator post extending from another wall of said second and/or third resonator (i.e., the common wall and/or the further common wall and/or a first wall of the second resonator and/or a first wall of the third resonator) into the respective cavity.

According to further exemplary embodiments, at least one of said walls (e.g., first wall and/or side wall and/or common wall and/or further common wall and/or common side wall and/or further common side wall) and or said lids (lid of a resonator and/or common lid) of any of said resonators may comprise or be made of electrically conductive material such as copper, and/or may at least comprise an electrically conductive surface.

According to further exemplary embodiments, the principle of vertically (i.e., along a longitudinal axis) stacking of resonators may be extended to greater numbers of resonators, i.e. 5 or more.

Further exemplary embodiments relate to a filter for radio frequency, RF, signals comprising at least one resonator according to the embodiments and/or at least one apparatus according to the embodiments.

Further exemplary embodiments relate to a method of filtering a radio frequency, RF, signal, comprising passing said RF signal through a filter according to the embodiments.

According to further exemplary embodiments, said method further comprises tuning at least one resonator (e.g., its resonant frequency) of said filter by at least axially moving said lid (i.e., the lid of the resonator cavity and/or a common lid arranged between two cavities) with respect to said at least one cavity facing said (common) lid.

BRIEF DESCRIPTION OF THE FIGURES

Some exemplary embodiments will now be described with reference to the accompanying drawings.

FIG. **1** schematically depicts a cross-sectional side view of a resonator according to exemplary embodiments,

FIG. **2**A, **2**B each schematically depict a cross-sectional side view of a resonator according to further exemplary embodiments,

FIG. **2**C schematically depicts a tuning frequency characteristic according to further exemplary embodiments,

FIG. **3**, **4**, **5**A, **5**B, **6**A each schematically depict a cross-sectional side view of a resonator according to further exemplary embodiments,

FIG. **6**B schematically depicts a top view of a first wall of a resonator according to further exemplary embodiments,

FIG. **7** schematically depicts a side view of an apparatus according to further exemplary embodiments,

FIG. **8** schematically depicts a cross-sectional side view of an apparatus according to further exemplary embodiments,

FIG. **9**A, **9**B each schematically depict a top view of a filter according to further exemplary embodiments,

FIG. **10** schematically depicts a cross-sectional side view of an apparatus according to further exemplary embodiments,

FIG. **11** schematically depicts a cross-sectional side view of an apparatus according to further exemplary embodiments,

FIG. **12**A schematically depicts a perspective view of a filter according to further exemplary embodiments,

FIG. **12**B schematically depicts a cross-sectional side view of the filter of FIG. **12**A,

FIG. **12**C schematically depicts operational parameters of a filter according to further exemplary embodiments, and

FIG. **13** schematically depicts a simplified flow-chart of a method according to further exemplary embodiments.

DESCRIPTION OF THE EMBODIMENTS

FIG. **1** schematically depicts a resonator **100** for radio frequency, RF, signals according to exemplary embodiments in a cross-sectional side view.

The resonator **100** comprises a cavity **110** having a longitudinal axis **110'**, a first wall **120**, at least one side wall **130**, and a lid **140** arranged opposite the first wall **120**, wherein said resonator **100** further comprises a guiding device **150** which is arranged at said at least one side wall **130** and is configured to guide an axial movement **A1** of said lid **140** along said longitudinal axis **110'**. This enables an efficient tuning of the resonator **100**, particularly of a resonant frequency of said resonator **100**. Thus, no further, separate tuning elements as known from conventional systems are required for tuning said resonator **100**.

According to further exemplary embodiments, said first wall **120** may be a bottom wall of the resonator **100**, and/or said lid **140** may be a top wall of the resonator **100**. Presently, the guiding means **150** is arranged in a first axial end section **110***a* of the cavity **110**, and the first wall **120** is arranged in a second axial end section **110***b* of the cavity **110**.

According to further exemplary embodiments, said cavity **110** may comprise a rectangular cross-section (in this case, e.g. four side walls pairwise parallel to each other may be provided). According to further exemplary embodiments, said cavity **110** may comprise a circular cross-section (in this case, e.g. said (single) side wall **130** may be provided, which may e.g. comprise a basically hollow circular cylindrical shape).

According to further exemplary embodiments, cf. the resonator **100***a* of FIG. **2**A, said guiding device **150***a* comprises a first thread **152**, preferably an internal (i.e., female) thread **152**, and said lid **140** comprises a second thread **142**, preferably an external (i.e., male) thread that fits to said first thread **152** of said guiding device **150***a*. Thus, a precise tuning of the resonator's resonant frequency is enabled by rotating said lid **140** within the guiding device **150***a*. In these embodiments, the guiding device **150***a* is configured to guide both a rotational movement (screwing motion) and said axial movement of the lid **140** with respect to the resonator's cavity **110**.

According to further embodiments, said lid **140** comprises a profile **144**, e.g. screw profile, for example a hexagonal profile similar to a hex nut, which facilitates driving a rotational movement of said lid **140**, e.g. for tuning the resonator cavity **110** associated with said lid **140**. According to further embodiments, said profile **144** is provided on a surface of said lid **144**, preferably an outer surface of said lid, to enable easy access from the outside of the resonator **100***a*.

According to further embodiments, said guiding device **150***a* of the resonator **100***a* of FIG. **2**A may also comprise a first thread which is an external thread (not shown), and said lid **140** may comprise a second thread **142** which is an internal thread that fits to said first thread of said guiding device. Thus, a precise tuning of the resonator's resonant frequency is enabled by rotating said lid **140** around the guiding device. In these embodiments, too, the guiding device is configured to guide both a rotational movement (screwing motion) and said axial movement of the lid **140** with respect to the resonator's cavity **110**.

FIG. **2**B depicts a resonator **100***b* according to further exemplary embodiments, wherein the guiding means **150***b* having an inner thread **152***a* are integrated into the side wall **130**.

FIG. **2**C schematically depicts a tuning frequency characteristic of a resonator according to further exemplary embodiments. Curve C1 depicts a resonant frequency over a first spatial coordinate x, which e.g. characterizes an axial position of the lid **140** (FIG. **1**) along the longitudinal axis **110'** of the cavity **110**. As can be seen from FIG. **2**C, the resonant frequency C1 changes linearly over the lid position x.

According to further exemplary embodiments, cf. the resonator **100***c* of FIG. **3**, said guiding device **150***c* comprises a first serrated surface **154** (e.g., in the form of a "step slide"), and said lid **140** comprises a second serrated surface **144** that fits to said first serrated surface **154** of said guiding device **150***c*. This enables a stepwise axial movement A**1** of said lid **140** relative to said cavity **110**, i.e. without rotation of said lid, i.e. tuning by means of setting different discrete axial positions for the lid **140** of resonator **100***c* of FIG. **3**, in contrast to the continuous movement that may be attained by the screwing motion of the lid **140** of the resonator **100***a* of FIG. **2**A. A step size of said stepwise axial movement may be controlled by providing the serrated surfaces **144**, **154** with a corresponding geometry.

According to further exemplary embodiments, guiding means **150***c* comprising said serrated surfaces **154** may be used with rectangular and/or circular cross-sections of said cavity **110**, while according to other exemplary embodiments guiding means **150***a* (FIG. **2**A) comprising threads are preferably used with a circular cross-section of said cavity **110**.

According to further exemplary embodiments, cf. the resonator **100***d* of FIG. **4**, said first wall **120** comprises at least one resonator post **122** extending into said cavity **110** (preferably perpendicular to an inner surface of said first wall, i.e. parallel to the longitudinal axis **110'**). According to further exemplary embodiments, said at least one resonator post **122** comprises a circular cylindrical shape. According to further exemplary embodiments, said at least one resonator post **122** comprises a hollow (circular) cylindrical shape, as exemplarily depicted by FIG. **4**. According to further exemplary embodiments, said at least one resonator post **122** is arranged coaxially with respect to the longitudinal axis **110'** of the cavity **110**.

According to further exemplary embodiments, said lid **140** comprises at least one resonator post **146** extending into said cavity **110**, preferably perpendicular to an inner surface of said lid **140**. According to further exemplary embodiments, said at least one resonator post **146** of said lid **140** comprises a circular cylindrical shape. According to further exemplary embodiments, said at least one resonator post **146** comprises a hollow (circular) cylindrical shape, as exemplarily depicted by FIG. **4**. According to further exemplary embodiments, said at least one resonator post **146** is arranged coaxially with respect to the longitudinal axis **110'** of the cavity **110** and/or an optional resonator post **122** extending from said first wall **120** into said cavity **110**.

According to further exemplary embodiments, cf. the resonator **100***e* of FIG. **5**A, said first wall **120** comprises at least one opening **124**, which enables to exchange RF signals A**2** and/or generally electromagnetic energy A**2** with an adjacent volume such as an optional neighboring further resonator, cf. the dashed rectangle **100'** of the configuration of FIG. **5**B. This enables to provide a particularly small configuration of several resonators **100***f*, **100'**, as depicted by FIG. **5**B, which may be coupled via said at least one opening **124**. This arrangement of resonators **100***f*, **100'** may also be referred to as "stacked configuration", because the first resonator **100***f* and the second resonator **100'** of FIG. **5**B are arranged together along the longitudinal axes of their cavities.

According to further exemplary embodiments, said at least one opening **124** of said first wall **120**, comprises a circular (and/or circular ring) shape, preferably arranged coaxial with the longitudinal axis of the cavity **110** of said resonator **100***f*.

According to further exemplary embodiments, cf. the resonator **100***g* of FIG. **6**A, a plurality of openings **124***a*, **124***c* may be provided in said first wall **120**, wherein preferably said plurality of openings is arranged circumferentially around said longitudinal axis **110'** (FIG. **1**) of the cavity **110**. According to further exemplary embodiments, at least one of said plurality of openings **124***a*, **124***c* may comprise a rectangular shape, preferably with rounded edges, cf. the top view of an exemplary configuration of the first wall **120** of FIG. **6**B. As can be seen, the first wall **120** presently comprises four rectangular openings **124***a*, **124***b*, **124***c*, **124***d* arranged circumferentially around the longitudinal axis (perpendicular to the drawing plane of FIG. **6**B), wherein said rectangular openings **124***a*, **124***b*, **124***c*, **124***d* have rounded edges. Double arrow A**4** indicates a rotational movement of the first wall **120** (e.g., in combination with the side wall(s) **130** (FIG. **1**)) which may be applied according to further exemplary embodiments, e.g. to attain a relative rotational movement between the walls **120**, **130** and the lid **140**.

Further exemplary embodiments, cf. FIG. **7**, relate to an apparatus **1000** comprising a first resonator **1100** according to the embodiments and at least one further resonator **1100'** for radio frequency, RF, signals, which is preferably coupled (cf. block arrow A**3**) with said first resonator **1100**. This way, a compact and mechanically stable configuration having two resonators may be provided, wherein at least the first resonator **1100** is efficiently tunable regarding its resonant frequency by means of at least axially moving its lid **140** (FIG. **1**).

According to further exemplary embodiments, more than two resonators **1100**, **1100'** may also be arranged together, preferably along their axial direction, e.g. in a stacked configuration, wherein at least two resonators of said configuration may be coupled with each other. However, according to further exemplary embodiments, two or more resonators **1100**, **1100'** may also be arranged together, preferably along their axial direction, e.g. in a stacked configuration, wherein no coupling between adjacent (or non-adjacent or between any) resonators of such stack may be provided.

According to further exemplary embodiments, said at least one further resonator **1100'** of said apparatus **1000** (FIG. **7**) may be a resonator according to the embodiments, e.g. having the configuration of any of the exemplarily depicted resonators **100***a* to **100***g* (or any combination thereof) as explained above with reference to FIG. **1** to FIG. **6**B. This way, a compact and mechanically stable configuration having two resonators **1100**, **1100'** may be provided, wherein at least the first resonator **1100** and the further resonator **1100'** are efficiently tunable regarding their resonant frequency by means of at least axially moving the respective lid.

According to further exemplary embodiments, said at least one further resonator **1100'** may be a conventional resonator. According to further exemplary embodiments, said first resonator and said at least one further resonator (or their respective cavities) are not coupled with each other.

According to further exemplary embodiments, cf. the apparatus **1000***a* of FIG. **8**, said at least one further resonator is a second resonator **1200**, wherein said second resonator **1200** comprises a configuration according to the embodiments. As can be seen from FIG. **8**, the first resonator **1100** of the apparatus **1000***a* basically comprises a configuration similar to the resonators **100***e*, **100***f* of FIG. **5**A, **5**B. According to further exemplary embodiments, said second resonator **1200** comprises a cavity **210** having a longitudinal axis **210'**, a first wall **220**, at least one side wall **230**, and a lid **240** arranged opposite the first wall **220**, wherein said second resonator **1200** further comprises a guiding device **250** which is arranged at said at least one side wall **230** and is configured to guide an axial movement of said lid **240** along said longitudinal axis **210'** (preferably at least an axial movement, in case of e.g. serrated surfaces, and both a rotational and axial movement in case of a thread connection between guiding device **250** and the lid **240**).

According to further exemplary embodiments, the first wall **120** of the first resonator **1100** and the first wall **220** of the second resonator **1200** are adjacent to each other forming a common wall **1020** of the apparatus **1000***a* which at least partly (e.g., apart from one or more optional openings **1024** for RF signal coupling A**3**) separates the cavity **110** of the first resonator **1100** and the cavity **210** of the second resonator **1200** from each other, wherein preferably said common wall **1020** comprises at least one opening **1024**. This enables a particularly small configuration of the apparatus **1000***a*, which may also be referred to as "stacked configuration", because the first resonator **1100** and the second resonator **1200** may be arranged together along the longitudinal axes **110'**,**210'** of their cavities. According to further exemplary embodiments, the first resonator **1100** and the second resonator **1200** are arranged relative to each other such that the longitudinal axes **110'**,**210'** of their respective cavities **110**, **210** are collinear.

According to further exemplary embodiments, said at least one opening **1024** of said common wall **1020** comprises a circular (and/or circular ring) shape, preferably arranged coaxial with the longitudinal axis **110'**,**210'** of at least one adjacent cavity **110**, **210**. According to further exemplary embodiments, a plurality of openings (not depicted in FIG. **8**) may be provided in said common wall, wherein preferably said plurality of openings is arranged circumferentially around the longitudinal axis of said at least one adjacent cavity. According to further exemplary embodiments, at least one of said plurality of openings may comprise a rectangular shape, preferably with rounded edges.

According to further exemplary embodiments, the cavity **110** of the first resonator **1100** may have a first geometry, e.g. particular cross-section (shape and/or size), and the cavity **210** of the second resonator **1200** may have a second geometry, e.g. particular cross-section, wherein said second geometry is different from said first geometry.

According to further exemplary embodiments, the second geometry may be similar or identical to the first geometry.

According to further exemplary embodiments, said at least one side wall **130** of the first resonator **1100** and said at least one side wall **230** of the second resonator **1200** are made of one piece forming a common side wall **1030** for both said first cavity **110** and said second cavity **210**, which yields a particularly compact configuration with high mechanical stability.

According to further exemplary embodiments, said common wall **1020** and said common side wall **1030** are made of one piece **1040**.

According to further exemplary embodiments, in a first axial end section **1040***a* of said piece **1040** (corresponding with a first axial end section **110***a* of the first resonator **1100**), a first guiding device **150** is provided enabling at least axial movement Ala of the lid **140** of the first resonator **1100** and thus individual tuning of the resonant frequency of the first resonator **1100**.

Similarly, according to further exemplary embodiments, in a second axial end section **1040***b* of said piece **1040** (corresponding with a first axial end section **210***a* of the second resonator **1200**), a second guiding device **250** is provided enabling at least axial movement A**1***b* of the lid **250** of the second resonator **1200** and thus individual tuning of the resonant frequency of the second resonator **1200**. This way, the resonant frequencies of both resonators **1100**, **1200** can efficiently be tuned from outside the apparatus **1000***a* (and independently from each other) by moving at least one of the lids **140**, **240**, while the cavities **110**, **210** are at least partly separated from each other by means of the common wall **1020** arranged in respective second axial end sections **110***b*, **210***b* of the cavities **110**, **210**.

According to further exemplary embodiments, the common wall **1020** comprises resonator posts **1022** extending into both adjacent cavities **110**, **210**, wherein said resonator posts **1022** presently comprise hollow circular cylindrical shape, similar to the resonator posts **122** of FIG. **5**A, **5**B. According to further exemplary embodiments, the opening **1024** is arranged radially inside said resonator posts **1022**. In other words, presently, the opening **1024** in the common wall **1020** corresponds with an interior of the hollow circular cylindrical shape of the resonator posts **1022**.

According to further exemplary embodiments, at least one of the lids **140**, **240** may also comprise at least one resonator post **146**, **246**, e.g. similar to the embodiments exemplarily depicted by FIG. **4**, **5**A, **5**B.

FIG. **9**A, **9**B each schematically depict a top view of a filter for RF signals according to further exemplary embodiments. The filter **2000** of FIG. **9**A comprises an apparatus **1000***b* having four apparatus **1000***a* according to FIG. **8**. In other words, the filter **2000** of FIG. **9**A comprises eight resonators, wherein two resonators each are stacked together in accordance with the FIG. **8** embodiment **1000***a*. This way, a compact and yet efficiently tunable RF filter **2000**, e.g. an eight-pole filter, may be provided, which may e.g. be integrated into an antenna system (not shown) for transmitting and/or receiving electromagnetic waves, e.g. RF signals.

In contrast, the further RF filter **2000'** of FIG. **9**B comprises an apparatus **1000***c* having four apparatus **1000***d*, which will be explained below with reference to FIG. **10**, wherein each apparatus **1000***d* comprises three resonators. In other words, the filter **2000'** of FIG. **9**B comprises twelve resonators, wherein three resonators each are stacked together in accordance with the FIG. **10** embodiment **1000***d*.

In the following, further exemplary embodiments are explained with reference to the apparatus **1000***d* of FIG. **10**. The apparatus **1000***d* comprises a first resonator **1100** and a second resonator **1200** with a common wall **1020** and common side wall **1030** forming one piece **1040**, as well as said guiding means **150**, **250**. Additionally, according to further exemplary embodiments, a third resonator **1300** with a cavity **310** is provided, wherein said third resonator **1300** comprises at least one side wall **330** and is arranged such that a first axial end section **310***a* of its cavity **310** faces the first axial end section **210***a* of the cavity **210** of the second resonator **1200**. Further, instead of the lid **240** of FIG. **8**, a common lid **1060** is provided between the second resonator **1200** and the third resonator **1300** (i.e., in a second axial end section **1040***b* of said one piece **1040**), said common lid **1060** at least partly (e.g., in the case of RF coupling openings, not shown in FIG. **10**), preferably fully, covering the cavity **210** of the second resonator **1200** and the cavity **310** of the third resonator **1300**. This way, a compact and mechanically stable configuration **1000***d* having three resonators **1100**, **1200**, **1300** may be provided, wherein at least the first resonator **1100** is efficiently tunable regarding its resonant frequency by means of at least axially moving its lid **140**.

According to further exemplary embodiments, said third resonator **1300** comprises a first wall **320** in a second axial end section **310***b* of the cavity **310**, which may optionally comprise at least one resonator post **322** extending into the cavity **310**, e.g. similar to resonator post **122** of FIG. **4**.

According to further exemplary embodiments, said second resonator **1200** comprises a guiding device **250** which is arranged at a first axial end section **210***a* of said cavity **210** of the second resonator **1200** and is configured to guide an axial movement A5 of said common lid **1060** with respect to said cavity **210** of the second resonator **1200** along a longitudinal axis **210'** of said cavity **210** of the second resonator **1200**. This enables to tune the resonant frequency of the cavity **210** of the second resonator **1200** by means of at least axially moving the common lid **1060**.

According to further exemplary embodiments, said guiding device **250** of said second resonator **1200** may have a configuration similar or identical to the guiding device **150** of the first resonator **1100**. This way, by axially moving the lid **140** of the first resonator **1100**, the resonant frequency of the cavity **110** of the first resonator **1100** may be tuned, and by axially moving the common lid **1060** relative to the cavity **210** of the second resonator **1200**, the resonant frequency of the cavity **210** of the second resonator **1200** may be tuned.

According to further exemplary embodiments, different resonators of an apparatus **1000***d*, however, may comprise different types of guiding devices. As an example, a first guiding device associated with a first cavity may comprise a thread mechanism **150***a* (FIG. **2**A), while a second guiding device associated with at least one further, e.g. second, cavity may comprise a step slide mechanism **150***b* (FIG. **2**B).

According to further exemplary embodiments, said third resonator **1300** (FIG. **10**) comprises a guiding device **350** which is arranged at a first axial end section **310***a* of said cavity **310** of the third resonator **1300** and is configured to guide an axial movement A5 of said common lid **1060** with respect to said cavity **310** of the third resonator **1300** along a longitudinal axis **310'** of said cavity **310** of the third resonator **1300**. This enables to tune the resonant frequency of the cavity **310** of the third resonator **1300** by means of at least axially moving the common lid **1060** relative to the cavity **310** of the third resonator **1300**.

According to further exemplary embodiments, said piece **1040** comprising said common wall **1020** and said common side wall **1030** may be moved, together with said common lid **1060** (i.e., there is no relative movement between said piece **1040** and said common lid **1060**), (at least) axially with respect to the third resonator **1300**, whereby the resonant frequency of the cavity **310** of the third resonator **1300** may be tuned, whereas the resonant frequency of the cavity **210** of the second resonator **1200** is not altered as the common lid **1060** is not moved axially with respect to said cavity **210** of the second resonator **1200** while tuning said third resonator **1300**.

According to further exemplary embodiments, said piece **1040** comprising said common wall **1020** and said common side wall **1030** may be moved axially with respect to the common lid **1060**, whereby the resonant frequency of the cavity **210** of the second resonator **1200** of the apparatus **1000***d* may be tuned, whereas the resonant frequency of the cavity **310** of the third resonator **1300**, which is adjacent to said common lid **1060**, is not altered as the common lid **1060** is not required to be moved axially with respect to said cavity **310** of the third resonator **1300** while tuning said second resonator **1200**.

According to further exemplary embodiments, said guiding device **250** of the second resonator **1200** comprises a thread **252**, preferably an inner (i.e., female) thread **252**, wherein said common lid **1060** also comprises a thread, preferably an outer (i.e., male) thread **1062***a* arranged at a radially outer section **1062** of the common lid **1060**, wherein said male thread **1062***a* of the common lid **1060** fits to said thread **252** of said guiding device **250** of the second resonator **1200**.

According to further exemplary embodiments, said guiding device **350** of the third resonator **1300** comprises a thread **352**, preferably an inner (i.e., female) thread **352**, wherein said common lid **1060** comprises said male thread **1062***a* that also fits to said thread **352** of said guiding device **350** of the third resonator **130**. This way, axial (and rotational) movement of the common lid **1060** with respect to both adjacent resonators **1200**, **1300** may be effected.

According to further exemplary embodiments, at least one lid **140**, **1060** of said apparatus **1000***d* comprises a circular cylindric shape, e.g. circular disc shape.

According to further exemplary embodiments, said common lid **1060** (FIG. **10**) comprises a circular cylindric shape, e.g. circular disc shape. According to further exemplary embodiments, said common lid **1060** may comprise said radially outer section **1062**, where said outer (i.e., male) thread **1062***a* is provided which fits to the inner thread **252** of said guiding device **250** of the second resonator **1200** and/or the guiding device **350** of the third resonator **1300**. According to further exemplary embodiments, said common lid **1060** is designed such that its outer thread **1062** can be screwed into both the inner thread **252** of the guiding device **250** of the second resonator **1200** and the inner thread **352** of the guiding device **350** of the third resonator **1300** at the same time.

According to further exemplary embodiments, an axial length (i.e., as seen parallel to a longitudinal axis **210'**,**310'** of the apparatus **1000***d* and/or at least one of its resonator cavities **210**, **310**) of said outer thread **1062***a* of the common lid **1060** is chosen such that a) it can be screwed into both the inner thread **252** of the guiding device **250** of the second resonator **1200** and the inner thread **352** of the guiding device **350** of the third resonator **1300** at the same time, thus mechanically coupling the second resonator **1200** and the third resonator **1300** with each other, and b) tuning of the second and/or third resonator is still possible, i.e. by screwing the common lid **1060** further into/out of the second and/or third resonator or the respective guiding devices **250**, **350** of said resonators **1200**, **1300**.

According to further exemplary embodiments, said common lid **1060** comprises at least one resonator post **1064**, **1064** extending into at least one cavity **210**, **310** adjacent to said common lid **1060**. According to further exemplary embodiments, said at least one resonator post **1064** of said common lid **1060** may be arranged on a first surface **1061***a* of said common lid **1060** facing the cavity **210** of the second resonator **1200**, such that said at least one resonator post **1064** of the common lid **1060** extends into said cavity **210** of the second resonator **1200**. According to further exemplary embodiments, at least one resonator post **1065** of said common lid **1060** may be arranged on a second surface **1061***b* of said common lid **1060** facing the cavity **310** of the third resonator **1300**, such that said resonator post **1065** of the common lid **1060** extends into said cavity **310** of the third resonator **1300**. According to further exemplary embodiments, at least one resonator post **1064**, **1065** of said common lid **1060** may be arranged on said first surface **1061***a* of said common lid **1060**, and at least one (further) resonator post **1065** of said common lid **1060** may be arranged on said second surface **1061***b*.

According to further exemplary embodiments, said at least one resonator post **1064**, **1065** of said common lid **1060** comprises a circular cylindrical shape. According to further exemplary embodiments, said at least one resonator post **1064**, **1065** of said common lid **1060** comprises a hollow (circular) cylindrical shape, cf. FIG. **10**. According to further exemplary embodiments, said at least one resonator post **1064**, **1065** of said common lid **1060** is arranged coaxially with respect to a longitudinal axis **210'**,**310'** of an adjacent cavity **210**, **310** (i.e., of the second and/or third resonator **1200**, **1300**) and/or with respect to an optional resonator post **222**, **322** extending from another wall **1020**, **320** of said second and/or third resonator **1200**, **1300** (i.e., the common wall **1020** and/or the first wall **320** of the third resonator **1300**) into the respective cavity.

According to further embodiments, at least one of the guiding devices **150**, **250**, **350** may also comprise an outer thread (not shown), and the (common) lid **140**, **1060** may comprise a corresponding inner thread (or two inner threads) (not shown) that fit(s) to said outer thread(s). As an example, according to further embodiments, the guiding devices **250**, **350** may comprise outer threads (not shown), and the radially outer section **1062** of the common lid **1060** may comprise inner threads (not shown) to cooperate with one of said outer threads of the guiding devices **250**, **350** each.

According to further exemplary embodiments, cf. the apparatus **1000***e* of FIG. **11**, a fourth resonator **1400** is provided in addition to the resonators **1100**, **1200**, **1300**. The first resonator **1100** and the second resonator **1200** of the apparatus **1000***e* of FIG. **11**, and the arrangement of the common lid **1060** of FIG. **11** are similar to the corresponding elements **1100**, **1200**, **1060** of the apparatus **1000***d* of FIG. **10**.

Further, as can be seen from FIG. **11**, said fourth resonator **1400** comprises a cavity **410**, a first wall **420**, and at least one side wall **430**, wherein a first wall **320** of the third resonator **1300** and the first wall **420** of the fourth resonator **1400** are adjacent to each other forming a further common wall **1021** (similar to common wall **1020** between the first and second resonator **1100**, **1200**), which at least partly (e.g., apart from one or more optional openings **1025** for RF signal coupling) separates the cavity **310** of the third resonator **1300** and the cavity **410** of the fourth resonator **1400** from each other. This way, a compact and mechanically stable configuration **1000***e* having four resonators **1100**, **1200**, **1300**, **1400** may be provided.

According to further exemplary embodiments, the shape of said fourth resonator **1400** is similar or identical to the shape of the first and/or second resonator **1200**. As an example, the fourth resonator **1400** may also comprise an (at least) axially movable lid **440** opposing said further common wall **1021**, which enables individual tuning of the resonant frequency of said fourth resonator.

According to further exemplary embodiments, said further common wall **1021** comprises at least one opening **1025**, which enables RF signal coupling between the cavity **310** of the third resonator **1300** and the cavity **410** of the fourth resonator **1400**. According to further exemplary embodiments, said at least one opening **1025** of said further common wall **1021** comprises a circular (and/or circular ring) shape, preferably arranged coaxial with the longitudinal axis **310'**,**410'** of at least one adjacent cavity.

According to further exemplary embodiments, a plurality of openings (not shown) may be provided in said further common wall **1021**, wherein preferably said plurality of openings is arranged circumferentially around the longitudinal axis of said at least one adjacent cavity. According to further exemplary embodiments, at least one of said plurality of openings may comprise a rectangular shape, preferably with rounded edges.

According to further exemplary embodiments, said at least one side wall **330** of the third resonator **1300** and said at least one side wall **430** of the fourth resonator **1400** are made of one piece forming a further common side wall **1031** for both the cavity **310** of the third resonator **1300** and the cavity **410** of the fourth resonator **1400**.

According to further exemplary embodiments, said further common wall **1021** and said further common side wall **1031** are made of one piece **1041**, which enables a mechanically stable and yet compact design.

According to further exemplary embodiments, said one piece **1041** is similar to said one piece **1040** comprising the first and second resonators **1100**, **1200**, so that common parts **1040**, **1041** may be provided to form the pairs **1100**, **1200** and **1300**, **1400** of resonators.

Tuning of any of the resonators **1100**, **1200**, **1300** of the apparatus **1000***e* of FIG. **11** may be effected as explained above with reference to FIG. **10**. Tuning of the fourth resonator **1400** of FIG. **11** may be effected by at least axially moving its lid **440** relative to the cavity **410** or the piece **1041**, which is enabled by providing a respective guiding device **450** in a second axial end section **1041***b* of the piece **1041**, whereas tuning of the third resonator **1300** may be effected by (at least) axially moving the common lid **1060** guided by the guiding means **350** arranged in a first axial end section **1041***a* of the piece **1041**, as explained above with respect to FIG. **10**.

According to further exemplary embodiments, it is also possible to provide a fixed first wall (not shown) instead of the lid **440** for the fourth resonator **1400**.

According to further exemplary embodiments, at least one of said walls (e.g., first wall **120**, **220**, **320**, **420** and/or side wall **130**, **230**, **330**, **430** and/or common wall **1020** and/or further common wall **1021** and/or common side wall **1030** and/or further common side wall **1031**) and or said lids (lid **140**, **240**, **340**, **440** of a resonator and/or common lid **1060**) of any of said resonators may comprise or be made of electrically conductive material such as copper, and/or may at least comprise an electrically conductive surface, e.g. a metallized surface.

Further exemplary embodiments relate to a filter for radio frequency, RF, signals comprising at least one resonator according to the embodiments and/or at least one apparatus according to the embodiments. Exemplary filters **2000**, **2000'** have already been explained above with reference to FIG. **9**A, **9**B.

FIG. **12**A schematically depicts a perspective view of a filter **2000***a* according to further exemplary embodiments. The filter **2000***a* comprises an input terminal **2002** for providing an RF input signal is to the filter **2000***a* and an output terminal **2004** where a filtered RF output signal os is provided. The filter **2000***a* further comprises four resonators **2100**, **2200**, **2300**, **2400**, wherein corresponding side walls (similar to side wall **130** of FIG. **1**) are not depicted in FIG. **12**A for the sake of clarity. Three common walls **2102**, **2104**, **2106** are depicted which (at least partly) separate the cavities of adjacent resonators from each other. As an example, common wall **2102** (at least partly) separates the cavities of the first and second resonators **2100**, **2200** from each other.

According to further exemplary embodiments, at least one of said common walls **2102**, **2104**, **2106** comprises one or more openings **124***a*, . . . to enable coupling of RF energy between adjacent cavities, wherein said openings may be similar or identical to the openings **124***a*, **124***b*, **124***c*, **124***d* explained above with reference to FIG. 6B. According to further exemplary embodiments, by arranging the openings in a symmetric manner around the resonator ground and/or the longitudinal axis of the filter **2000***a*, the coupling between two resonators can be made independent of a rotation (or rotation angle) of individual resonators (and/or common walls) (which may, according to further embodiments be attained e.g. by a common lid **1060** (FIG. **10**), wherein presently the wall **2104** may implement the function of the common lid **1060** of FIG. **10**). Thus, if, according to further exemplary embodiments, rotation (e.g. of a lid **140**, **1060**) is employed to tune the resonant frequency of individual resonators, the (degree/amount of) coupling between adjacent resonators by means of said openings **124***a*, . . . , **124***d* is not affected by said rotation. Furthermore, in the case of more than two resonators, like in the filter **2000***a* of FIG. **12**A, this method of coupling allows to reduce an amount of possible unwanted cross coupling that distorts a frequency response of the filter **2000***a*. These two features of the coupling method using said openings **124***a*, . . . , **124***d* according to further exemplary embodiments make this coupling particularly useful together with the principle of frequency tuning enabled by further exemplary embodiments.

According to further exemplary embodiments, the common walls **2102**, **2104**, **2106** of the filter **2000***a* of FIG. **12**A may comprise a circular disc shape instead of the exemplarily depicted rounded rectangular shape of FIG. **12**A. According to further exemplary embodiments, at least one of the common walls **2102**, **2104**, **2106** may be provided with an external thread (not shown) and/or a serrated surface, and at least one side wall (not shown) any of the resonators **2100**, **2200**, **2300**, **2400** may comprise corresponding guiding means (not shown) that are configured to guide at least an axial movement of at least one of said common walls **2102**, **2104**, **2106** with respect to an adjacent cavity. According to further exemplary embodiments, at least one of the resonators **2100**, **2400** may comprise at its respective axial end section **2100***a*, **2400***a* at least one lid **140** (FIG. **1**) according to the embodiments.

According to further exemplary embodiments, guiding means comprising serrated surfaces **154** (FIG. **3**) may be provided for the exemplarily depicted basically rectangular common walls **2102**, **2104**, **2106** of the filter **2000***a* of FIG. **12**A.

FIG. **12**B schematically depicts a cross-sectional side view of the filter **2000***a* of FIG. **12**A.

FIG. **12**C schematically depicts operational parameters of the filter **2000***a* of FIG. **12**A. Curve **C2** depicts scattering parameter $S_{1,2}$ over frequency f, and curve **C3** depicts scattering parameter $S_{2,2}$ over frequency f.

Further exemplary embodiments relate to a method of filtering a radio frequency, RF, signal, comprising passing said RF signal through a filter according to the embodiments. FIG. **13** schematically depicts a simplified flow-chart of a corresponding method according to further exemplary embodiments.

The method comprises a step **510** of passing an RF input signal is (FIG. **12**A) through a filter **2000***a*. Step **510** e.g. comprises providing said RF input signal is to an input terminal **2002** of said filter **2000***a* and obtaining an output RF signal os, which corresponds to the filtered RF input signal, at an output terminal **2004** of said filter **2000***a*.

According to further exemplary embodiments, said method further comprises at least one optional step **500**, **520** of tuning at least one resonator (e.g., its resonant frequency) of said filter **2000***a* by at least axially moving a lid **140** (FIG. **1**) and/or a common lid **1060** or common wall **2102**, **2104**, **2106** adjacent to a cavity of said resonator with respect to said cavity facing said (common) lid.

According to further exemplary embodiments, the filter **2000** of FIG. **9**A, which comprises four apparatus **1000***a* according to FIG. **8**, may be tuned (steps **500**, **520** of FIG. **12**C) by moving any of the lids **140**, **240** of its respective resonators. Thus, an efficient tuning of individual resonant frequencies of any of the eight resonators of said filter **2000** is enabled, which advantageously may also be performed in the field, e.g. when the filter **2000** is mounted in a target system such as a transceiver or an antenna for a communications system.

According to further exemplary embodiments, the tuning principle based on the (common) lid **140**, **1060** may be applied to any type of cavity resonator, e.g. air-filled resonators and/or dielectric-filled resonators.

Further exemplary embodiments enable to provide resonators and filters for RF signals that comprise at least one of the following advantages: compact size, low cost, low loss, easily tunable, without sacrificing performance, enabling a compact integration with a target system such as an antenna and/or transceiver.

Further exemplary embodiments are particularly suited for use with 5G (fifth generation) communications systems, which are e.g. based on massive MIMO (multi-input multi-output) techniques that may require that one or two transceivers are provided per one or two or more antenna elements, which may drastically increase the number of transceivers required—as compared to other radio communications systems. According to further exemplary embodiments, in order to provide an antenna (system) with a great number of radiating elements closely spaced together, the transceivers supporting each antenna element may be physically placed behind each antenna element (with respect to a main direction of radiation, e.g. a main lobe of the antenna characteristic). In this context, according to further exemplary embodiments, RF filters for the antenna(s) may be physically arranged behind the radiating element(s) of the antenna(s), wherein such compact integration is facilitated by the RF resonators and RF filters according to further exemplary embodiments.

The invention claimed is:

1. An apparatus comprising:

a first resonator for radio frequency, RF, signals, with a cavity having a longitudinal axis, said first resonator comprising a first wall, at least one side wall, and a lid arranged opposite the first wall;

a second resonator for RF signals, with a respective cavity having a respective longitudinal axis, the second resonator comprising a respective first wall, at least one respective side wall, and a respective lid arranged opposite the respective first wall; and

a third resonator for RF signals, with a corresponding cavity, said third resonator comprising at least one corresponding side wall and being arranged such that an axial end section of the corresponding cavity faces an axial end section of the respective cavity;

wherein said first resonator further comprises a guiding device arranged at said at least one side wall of said first resonator and configured to guide an axial movement of said lid of said first resonator along said longitudinal axis of said first resonator;

wherein the first wall of said first resonator and the respective first wall are adjacent to each other forming a common wall which at least partly separates the cavity of said first resonator and the respective cavity from each other; and

wherein a common lid is provided between said second resonator and said third resonator, said common lid at least partly covering the respective cavity and the corresponding cavity and being movable along the respective longitudinal axis.

2. The apparatus according to claim **1**, wherein said common wall has at least one opening therein.

3. The apparatus according to claim **1**, wherein said at least one side wall of said first resonator and said at least one respective side wall are made of one piece forming a common side wall for both said cavity of said first resonator and said respective cavity.

4. The apparatus according to claim **1**, wherein said apparatus further comprises a fourth resonator for RF signals, which is coupled with said third resonator.

5. The apparatus according to claim **1**, wherein said guiding device comprises a first thread, and wherein said lid of said first resonator comprises a second thread that fits to said first thread of said guiding device.

6. The apparatus according to claim **1**, wherein said guiding device comprises a first serrated surface, and wherein said lid of said first resonator comprises a second serrated surface that fits to said first serrated surface of said guiding device.

7. The apparatus according to claim **1**, wherein said guiding device is arranged in a first axial end section of said cavity of said first resonator, and wherein said first wall is arranged in a second axial end section of said cavity of said first resonator.

8. A filter for radio frequency, RF, signals comprising at least one apparatus, said at least one apparatus comprising:

a first resonator for, RF signals, with a cavity having a longitudinal axis, said first resonator comprising a first wall, at least one side wall, and a lid arranged opposite the first wall;

a second resonator for RF signals, with a respective cavity having a respective longitudinal axis, the second resonator comprising a respective first wall, at least one respective side wall, and a respective lid arranged opposite the respective first wall; and

a third resonator for RF signals, with a corresponding cavity, said third resonator comprising at least one corresponding side wall and being arranged such that an axial end section of the corresponding cavity faces an axial end section of the respective cavity;

wherein said first resonator further comprises a guiding device arranged at said at least one side wall of said first resonator and is configured to guide an axial movement of said lid of said first resonator along said longitudinal axis of said first resonator;

wherein the first wall of the said first resonator and the respective first wall are adjacent to each other forming a common wall which at least partly separates the cavity of said first resonator and the respective cavity of the second resonator from each other; and

wherein a common lid is provided between said second resonator and said third resonator, said common lid at least partly covering the respective cavity and the corresponding cavity and being movable along the respective longitudinal axis.

9. The filter according to claim **8**, wherein said at least one side wall of said first resonator and said at least one respective side wall are made of one piece forming a common side wall for both said cavity of said first resonator and said respective cavity.

10. The filter according to claim **8**, wherein said apparatus further comprises a fourth resonator for RF signals, which is coupled with said third resonator.

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